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EBASCO

REM III PROGRAM

REMEDIAL PLANNING ACTIVITIES AT SELECTED UNCONTROLLED HAZARDOUS SUBSTANCE DISPOSAL SITES

EPA CONTRACT 68-01-7250

EBASCO SERVICES INCORPORATED

EPA WORK ASSIGNMENT NUMBER: 37-2LB8
EPA CONTRACT NUMBER: 68-01-7250
EBASCO SERVICES INCORPORATED

VINELAND CHEMICAL COMPANY SITE
FINAL DRAFT
REMEDIAL INVESTIGATION REPORT
UNION LAKE
VINELAND, NEW JERSEY

JUNE 1989

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REMEDIAL INVESTIGATION REPORT
UNION LAKE
VINELAND, NEW JERSEY

JUNE 1989

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6242b

TABLE OF CONTENTS

Section	Title	Page
LIST OF TABLES		iv
LIST OF FIGURES		vi
LIST OF ACRONYMS		vii
EXECUTIVE SUMMARY		E-1
1.0	INTRODUCTION	1-1
1.1	REMEDIAL INVESTIGATION OBJECTIVES	1-1
1.2	BACKGROUND INFORMATION	1-6
1.2.1	Site Description	1-6
1.2.2	Site History	1-14
1.2.3	Permit Actions	1-16
1.2.4	Previous Investigations	1-17
1.2.5	Community Concerns	1-22
1.3	REMEDIAL INVESTIGATION STUDY	1-23
1.3.1	Initial Activities	1-23
1.3.2	Field Investigation	1-23
1.3.3	Bench-Scale Studies	1-24
1.3.4	Risk Assessment	1-25
1.4	OVERVIEW OF REMEDIAL INVESTIGATION REPORT	1-25
2.0	SITE FEATURES INVESTIGATION	2-1
2.1	DESCRIPTION OF THE UNION LAKE STUDY AREA	2-1
2.2	DEMOGRAPHICS	2-1
2.3	LAND USE	2-4
2.4	NATURAL RESOURCES	2-5
2.5	CLIMATOLOGY	2-6
2.6	CULTURAL RESOURCES	2-6
2.7	DAM RECONSTRUCTION	2-7
2.8	SURFACE AND GROUNDWATER HYDROLOGY	2-8
3.0	HAZARDOUS SUBSTANCES INVESTIGATION	3-1
3.1	WASTE TYPES	3-1
3.2	WASTE COMPONENT CHARACTERISTICS AND BEHAVIOR	3-1
3.2.1	Environmental Transport and Fate	3-1
3.2.2	Waste Component Toxicity	3-12
3.2.3	Bioaccumulation in Aquatic Animals	3-14
3.2.4	Metabolism and Biotransformation	3-16
4.0	SURFACE WATER AND SEDIMENT INVESTIGATION	4-1
4.1	APPROACH	4-1
4.1.1	Sample Locations	4-1
4.1.2	Sampling Methods	4-7

TABLE OF CONTENTS (Cont'd)

Section	Title	Page
	4.1.3 Quality Assurance and Quality Control	4-9
	4.1.4 Bathymetric Mapping of Union Lake	4-10
	4.2 FIELD INVESTIGATION RESULTS	4-12
	4.2.1 NJDEP Results	4-13
	4.2.2 Ebasco Phase I Results	4-18
	4.2.3 Ebasco Phase II Results	4-24
	4.3 CONSIDERATIONS FOR REMEDIAL ALTERNATIVES	4-24
5.0	BIOTA INVESTIGATION	5-1
	5.1 APPROACH	5-1
	5.1.1 Sampling Locations	5-1
	5.1.2 Sampling Methods	5-1
	5.1.3 Quality Assurance and Quality Control	5-2
	5.2 FIELD INVESTIGATION RESULTS	5-2
6.0	BENCH-SCALE TREATABILITY TESTS	6-1
	6.1 SEDIMENT FIXATION TEST	6-1
	6.1.1 Objectives	6-1
	6.1.2 Description of Test	6-2
	6.1.3 Results	6-4
	6.1.4 Conclusion	6-5
	6.2 ARSENIC EXTRACTION FROM SEDIMENT TEST	6-5
	6.2.1 Objectives	6-5
	6.2.2 Description of Test	6-6
	6.2.3 Results	6-7
	6.2.4 Conclusion	6-7
7.0	PUBLIC HEALTH AND ENVIRONMENTAL CONCERNS	7-1
	7.1 PUBLIC HEALTH METHODOLOGY	7-1
	7.1.1 Hazard Identification	7-1
	7.1.1.1 Organic Chemicals	7-3
	7.1.1.2 Inorganic Chemicals	7-3
	7.1.2 Toxicological Summary	7-4
	7.2 EXPOSURE ASSESSMENT	7-10
	7.2.1 Ingestion of Vegetables and/or Forage Crops	7-10
	7.2.2 Ingestion of Lake Water	7-11
	7.2.3 Ingestion of Soil/Lake Sediment	7-11
	7.2.4 Ingestion of Fish	7-11
	7.2.5 Inhalation of Soil/Former Lake Sediment	7-11
	7.2.6 Direct Contact with Lake Sediment	7-12
	7.2.7 Direct Contact with Lake Water	7-12

TABLE OF CONTENTS (Cont'd)

Section	Title	Page
7.3	QUANTITATIVE EXPOSURE MODELS	7-12
7.3.1	Ingestion of Lake Sediment	7-16
7.3.2	Ingestion of Lake Water	7-19
7.3.3	Ingestion of Fish	7-20
7.3.4	Inhalation of Soil/Former Lake Sediment	7-22
7.3.5	Direct Contact with Lake Water	7-25
7.4	PUBLIC HEALTH IMPACTS FOR UNION LAKE	7-25
7.5	CONSIDERATIONS FOR REMEDIAL ALTERNATIVES	7-29
8.0	SUMMARY OF THE REMEDIAL INVESTIGATION	8-1
8.1	BACKGROUND	8-1
8.2	SITE FEATURES	8-1
8.3	HAZARDOUS SUBSTANCES INVESTIGATION	8-1
8.4	SURFACE WATER AND SEDIMENT INVESTIGATION	8-2
8.5	BIOTA INVESTIGATION	8-3
8.6	TREATABILITY STUDIES	8-3
8.7	RISK ASSESSMENT	8-3
8.8	RECOMMENDATIONS FOR FUTURE WORK	8-4
REFERENCES		8-6
Appendix A	Flora and Fauna Observed in the Union Lake Area	
Appendix B	Laboratory Report for the Chemical Fixation of Arsenic and Solidification of Sediment Treatability Study	
Appendix C	Laboratory Report of the Extraction of Arsenic from Sediment Treatability Study	
Appendix D	Field Water Quality Results	

LIST OF TABLES

Table Number	Title	Page
1-1	RI and FS Reports for the Vineland Chemical Company Site	1-2
1-2	Chemicals Used, Manufactured or Stored at Vineland Chemical Plant	1-11
3-1	Estimated Union Lake Partition Coefficient Data	3-11
3-2	Bioconcentration Factors of Arsenic for Five Fish Species in Union Lake	3-17
4-1	Ebasco Phase I Sampling Summary	4-2
4-2	Ebasco Phase II Sampling Summary	4-6
4-3	New Jersey Department of Environmental Protection Analytical Results of Sediment Core Samples Collected from Union Lake August, 1986	4-17
4-4	Ebasco Phase I Surface Water Analytical Results	4-19
4-5	Ebasco Phase I Sediment Analytical Results	4-22
4-6	Ebasco Phase II Surface Water Analytical Results	4-23
4-7	Concentration Ranges of Total Arsenic Levels in Union Lake Sediment Samples	4-25
4-8	Concentration Ranges of Total Dissolved and Particulate Arsenic in Union Lake Surface Water Samples	4-26
5-1	Arsenic, Pesticide and PCB Results for Five Fish Species	5-3
6-1	Summary of Treatability Tests for the Chemical Fixation and Solidification of Arsenic in Sediment	6-3
6-2	Summary of Treatability Tests for the Extraction of Arsenic from Sediment	6-8

LIST OF TABLES (Cont'd)

Table Number	Title	Page
7-1	A Comparison of Background Metal Concentrations at the Vineland Site with NJ Lakewood and Typical U.S. Soils	7-2
7-2	Carcinogenic Potency Factors for Contaminants Found in Union Lake	7-6
7-3	Toxicity Data for Noncarcinogens	7-7
7-4	Water Quality Regulatory Criteria	7-8
7-5	Summary of Equations Used to Calculate Chronic Daily Intakes For Union Lake	7-14
7-6	Parameters for Recreational Exposures to Union Lake Water and Sediment	7-17
7-7	Chemical Contamination in Fish from Union Lake	7-21
7-8	Contaminant Intake and Cancer Risk Estimates For Union Lake Fish Ingestion Pathway	7-23
7-9	Summary of Cancer Risks for Exposure Pathways at Union Lake	7-27
7-10	Arsenic Cancer Risks from Union Lake: Four Scenarios of Lake Conditions	7-28
7-11	Calculated Risks from Sediments at Various Arsenic Concentrations	7-31

LIST OF FIGURES

Figure Number	Title	Page
1-1	Vineland Chemical Company Regional Location Map	1-3
1-2	Vineland Chemical Company Site Study Area	1-4
1-3	Vineland Chemical Company One Mile Radius	1-7
1-4	Residential Locations Surrounding Vineland Chemical Company Site	1-8
1-5	Vineland Chemical Company Site Plan	1-9
1-6	Blackwater Branch	1-10
2-1	Union Lake Bathymetry	2-2
2-2	Union Lake Estimated Pool Size at the Draw Down Condition	2-3
2-3	Existing Water System, Millville, N.J.	2-10
3-1	Bacterial Reduction of Arsenate	3-4
3-2	The Biological Cycle for Arsenic	3-5
3-3	pH-pe Oxidation - Reduction Stability Diagram for Arsenic Compounds	3-8
4-1	Ebasco Sampling Stations	4-5
4-2	Fathometer Trace from Traverse E of Union Lake Bathymetric Survey	4-11
4-3	New Jersey Department of Environmental Protection (NJDEP) 1986 Sediment Sampling Stations	4-14
4-4	Arsenic Concentrations in Surficial Sediments (NJDEP and Ebasco, 1986)	4-15
4-5	Percent Sand Values in Surficial Sediments (NJDEP, 1986)	4-16

LIST OF ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
AIC	Acceptable Chronic Intake
ARARs	Applicable or Relevant and Appropriate Requirements
ASC	Acceptable Soil Concentration
ASTM	American Society of Testing and Materials
AWQC	Ambient Water Quality Criteria
BEHP	bis(2-ethylhexyl)phthalate
BNA	Base-Neutral/Acid Extractables
°C	Degrees Centigrade
CDI	Chronic Daily Intake
CDL	Contract Detection Limit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CLP	Contract Laboratory Program
CRAVE	Carcinogen Risk Assessment Verification Endeavor
DMAA	Dimethyl Arsenic Acid
DQO	Data Quality Objectives
ECRA	New Jersey Environmental Cleanup Responsibility Act
EDTA	Ethylenediaminetetra-acetate
EM	Electro Magnetic Conductivity Survey
EP	Extraction Procedure
EPIC	Environmental Photographic Information Center
ER	Ebasco River Sampling Station
EW	Ebasco Well
FS	Feasibility Study
GPD	Gallons Per Day
GPM	Gallons Per Minute
HEA	Health Effects Assessment
HSL	Hazardous Substances List
IDL	Instrument Detection Limit
IRIS	Integrated Risk Information System
Kd	Partitioning Coefficient
LL	Lined Lagoon
MCLGs	Maximum Contaminant Level Goals
MCLs	Maximum Contaminant Levels
MEP	Multiple Extraction Procedure
MG/KG	Milligrams Per Kilogram
MG/L	Milligrams Per Liter
MMAA	Monomethyl Arsenic Acid
MSL	Mean Sea Level
MW	Monitoring Well
NCDC	National Climatic Data Center
NCP	National Contingency Plan
NJAC	New Jersey Administrative Code
NJDEP	New Jersey Department of Environmental Protection
NJPDES	New Jersey Pollution Discharge Elimination System
NOAA	National Oceanic and Atmospheric Administration
ODW	Office of Drinking Water
OHEA	Office of Health and Environmental Affairs
OSHA	Occupational Safety and Health Administration

PCB	Polychlorinated Biphenyls
PMSA	Primary Metropolitan Statistical Area
PPB	Parts Per Billion
PPM	Parts Per Million
PSI	Pounds Per Square Inch
PVC	Polyvinyl Chloride
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RMCL	Recommended Maximum Contaminant Level
RfD	Reference Dose
SAS	Special Analytical Services
SNARL	Suggested-No-Adverse Response Level
SPDES	State Pollution Discharge Elimination System
SU	Standard Units
TCE	Trichloroethylene
TCL	Target Compound List
TOC	Top of Casing
TOC	Total Organic Carbon
UCS	Unconfined Compressive Strength
UG/L	Micrograms Per Liter
UL	Unlined Lagoon
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UV	Ultraviolet
VES	Vertical Electrical Soundings
ViChem	Vineland Chemical Company

EXECUTIVE SUMMARY

The Union Lake Remedial Investigation (RI) is one of three RIs being performed for the Vineland Chemical Company (ViChem) work assignment. The RIs include:

- The ViChem plant site proper;
- The River areas, consisting of the Blackwater Branch upstream of the plant to its confluence with the Maurice River; the Maurice River from the Blackwater Branch to Union Lake, approximately seven river miles downstream; and the Maurice River below Union Lake to the Delaware Bay, an approximate river distance of 25 miles; and
- Union Lake, an 870-acre impoundment on the Maurice River.

The purpose of the Union Lake RI was to collect sufficient data to prepare a risk assessment and to perform a feasibility study (FS) to evaluate potential remedial alternatives for environmental media found to cause increased health risks. The risk assessment evaluated contamination within the lake's sediments, water, and fish. The FS will concentrate on the lake sediments.

The ViChem site is ranked among the top 10 hazardous waste sites in New Jersey, and is ranked number 42 on the National Priorities List. ViChem has manufactured organic arsenical herbicides and fungicides at this plant since 1949.

Detailed information on past use, storage, and disposal of all process materials at the plant is not available. It is known that waste salts containing arsenic were piled outdoors, and that precipitation contacting the piles flushed arsenic into the groundwater. The contaminated groundwater subsequently discharged into the Blackwater Branch and was distributed downstream in the Maurice River drainage system.

Previous investigations have shown elevated arsenic concentrations in surface waters and sediments extending approximately 26 river miles downstream of the plant to the Delaware Bay. Union Lake was shown to impound and store contaminated sediments.

Union Lake is located in the City of Millville, New Jersey. In the past, the lake had been used extensively for recreational activities. The dam at the southern end of the lake is the oldest in the state, and the spillway is currently being rebuilt. During reconstruction, the water level of the lake has been lowered approximately eight to nine feet.

Because of the potential health risks posed by exposure to arsenic contamination in the lake sediments, recreational activities in the lake have been restricted by the NJDEP during the drawdown condition.

This RI was conducted in two phases. Phase I took place in June and July of 1986. Activities included sampling surface waters and sediments, and preparing a bathymetric map of the lake. Phase II took place in January of 1987. Activities included sampling surface water and fish. Some of the sampling in both phases was conducted at locations previously sampled by the NJDEP and others, while other sampling locations were chosen to broaden the data base.

Two bench scale treatability tests, chemical fixation and chemical extraction, were performed on the sediments. The fixation test was performed to determine if arsenic in the sediment could be chemically stabilized or physically bound to the sediment such that leachable arsenic concentrations were less than 5 mg/l. The extraction test was performed to determine if arsenic could be removed from the sediment to a concentration of 20 mg/kg, the background arsenic concentration of soils in New Jersey.

The major findings of the Union Lake RI were as follows:

- The sediment and water in Union Lake both had elevated arsenic concentrations. Many sediment samples had arsenic concentrations exceeding 20 mg/kg. Many water samples had arsenic concentrations greater than 50 ug/l, the Federal Primary Drinking Water Standard for arsenic.

- The risk assessment considered a number of pathways whereby the public could be exposed to the lake's water, sediments, and fish. Arsenic was found to be the main contaminant of concern. Health risks were screened on a worst case basis, using maximum concentrations, and on a best estimate basis, using mean concentrations. Health risks were evaluated for the lake at its normal pool elevation, and for various durations of lake drawdown. There was essentially no difference in the risks calculated for the various drawdown/lake full scenarios. The total arsenic risks from sediment and water were 1×10^{-5} using mean arsenic concentrations, and 7×10^{-4} using maximum arsenic concentrations. Increased potential health risks calculated for fish ingestion were primarily a result of PCB's found in the fish, which are believed to be unrelated to the ViChem site. The sediment arsenic concentration producing a risk of 1×10^{-5} was calculated to be approximately 120 ppm.

- The treatability studies determined that both chemical fixation and extraction were feasible methods to treat the arsenic contaminated sediments. The FS will evaluate both treatment methodologies.

The data collected in Phases I and II and the previous NJDEP data were sufficient to meet the study objectives of performing a risk assessment and performing an FS to evaluate remedial alternatives for the contaminated sediments. Further characterization of the lake sediments will be necessary for design if remediation of the lake sediment contamination is proposed in the future. Furthermore, there are upstream sources of arsenic to the lake. Any remedial action in the lake should be phased appropriately with upstream remedial actions to eliminate the sources of arsenic into the basin.

1.0 INTRODUCTION

The U.S. Environmental Protection Agency (USEPA) on May 9, 1986 authorized Ebasco Services Incorporated (Ebasco) to conduct a Remedial Investigation/Feasibility Study (RI/FS) on the Vineland Chemical Company (ViChem) site, Vineland, New Jersey. The RI/FS was performed in response to Work Assignment Number 37-2LB8 under Contract Number 68-01-7250. Preparation of this report was accomplished pursuant to the approved Work Plan for the ViChem site dated November 17, 1986 as amended in October 1987.

Three RI and three FS reports have been prepared for the ViChem site. The reports, the areas they cover, and the dates of submission to the USEPA are presented in Table 1-1.

The study area is approximately 38 miles long: 11 miles of riverine environment (including two miles upstream of the plant); 2 miles of lacustrine environment; and 25 miles of estuarine environment. This report addresses Union Lake. The location of the study area is shown in Figures 1-1 and 1-2.

1.1 REMEDIAL INVESTIGATION OBJECTIVES

The objective of the Union Lake RI was to obtain the data required to conduct a risk assessment and to perform an FS to evaluate potential remedial alternatives. Specifically the Union Lake RI objectives were threefold:

- Define the extent of contamination in the surface water, sediment, and fish in Union Lake;
- Conduct bench-scale studies to evaluate the feasibility of treating contaminated sediments, and to evaluate the potential impacts of proposed remedial measures; and
- Identify the contaminants and pathways that have actual or potential impacts on public health or the environment.

Ebasco's field investigation for the Union Lake RI was performed in two phases. Phase I, conducted in June and July, 1986, was performed to document and confirm the extent of arsenic contamination in the water and sediment. Phase II was conducted in January 1987 to supplement the sampling and analytical work performed by Ebasco during Phase I, and the work performed by the NJDEP in 1979, 1982, 1983, and 1986. The objective of these investigations is explained in Subsection 1.3.2. The results of Ebasco's Phase I and Phase II investigations, and the results of the NJDEP investigations, are presented in Section 4.2. These investigations provided the data to meet the study objectives.

TABLE 1-1

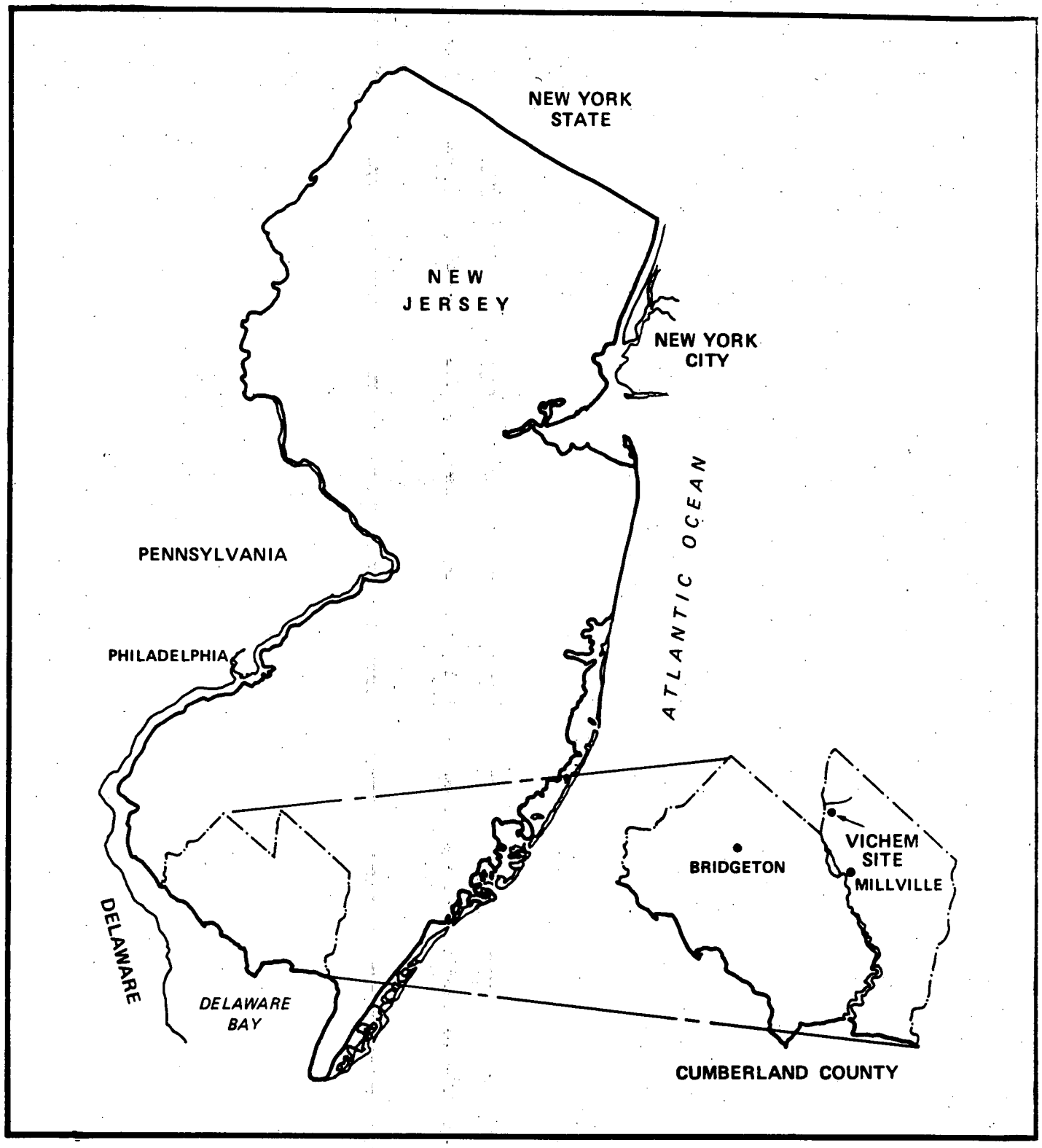
RI AND FS REPORTS PREPARED FOR THE VINELAND CHEMICAL COMPANY SITE

TITLE	AREAS	MEDIA INVESTIGATED	DRAFT	REVISED DRAFT	FINAL DRAFT
Plant Site RI	ViChem Plant Site	Soil, Groundwater	7/19/88	3/10/89	6/23/89
River Areas RI	Blackwater Branch, Maurice River between Blackwater Branch and Union Lake, Maurice River below Union Lake to Delaware Bay	Sediment, Surface Water, Biota	9/8/88	2/17/89	6/23/89
Union Lake RI(1)	Union Lake	Sediment, Surface Water, Biota	6/21/88	4/28/89	6/23/89
Plant Site FS	ViChem Plant Site	Soil, Groundwater	9/20/88	3/10/89	6/23/89
River Areas FS(2)	Blackwater Branch, Maurice River between Blackwater Branch and Union Lake	Sediment	10/5/88	2/17/89(3)	6/23/89
Union Lake FS	Union Lake	Sediment	1/18/89	4/14/89	6/23/89

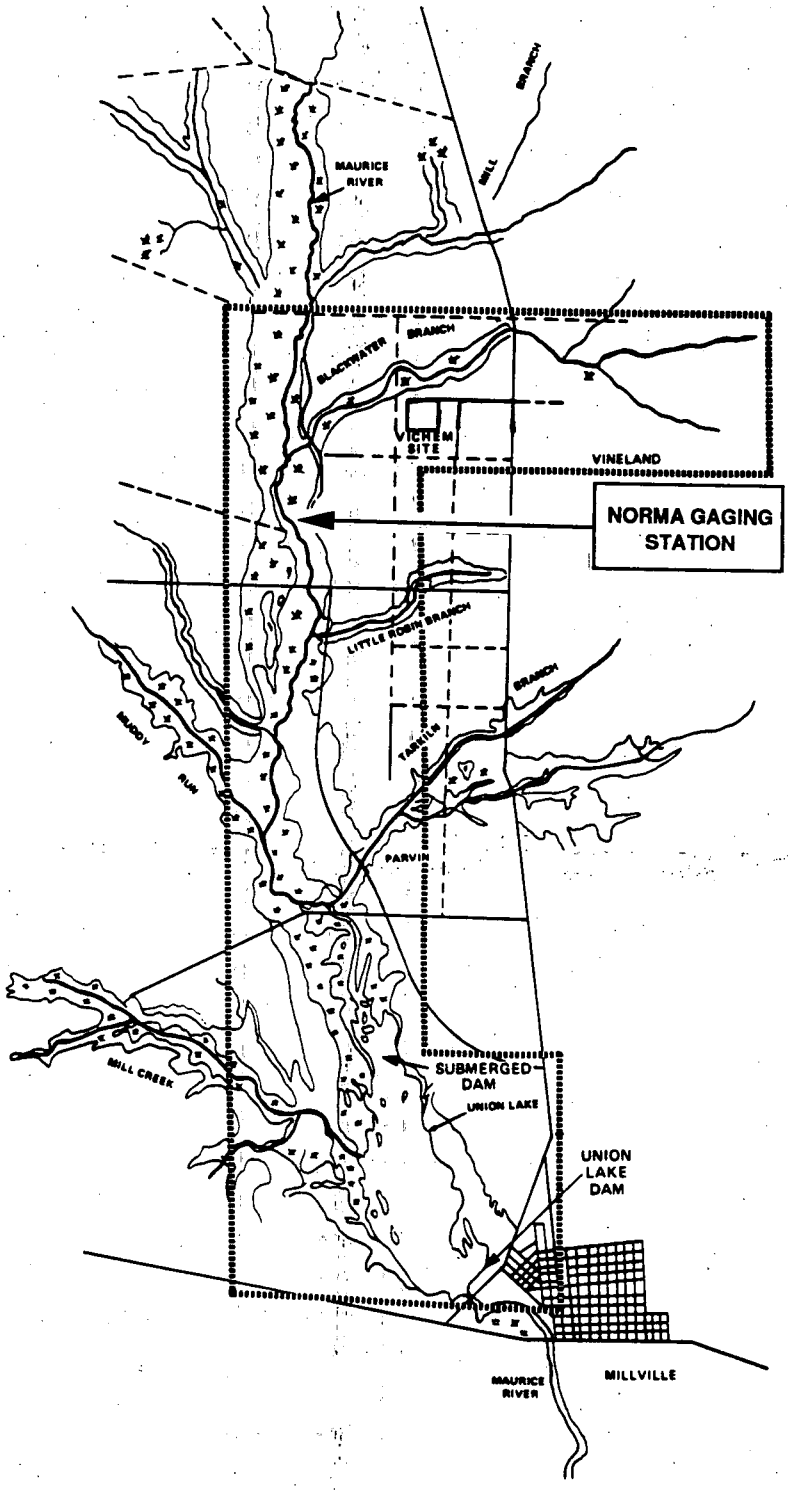
1 Risk assessment submitted on April 20, 1987. First Draft RI submitted on March 13, 1988. The June 21, 1988 RI incorporated the first revised risk assessment.

2 No FS Report is being prepared for the Maurice River below Union Lake.

3 This report was reissued on April 27, 1989 containing a revised action level for the sediments.

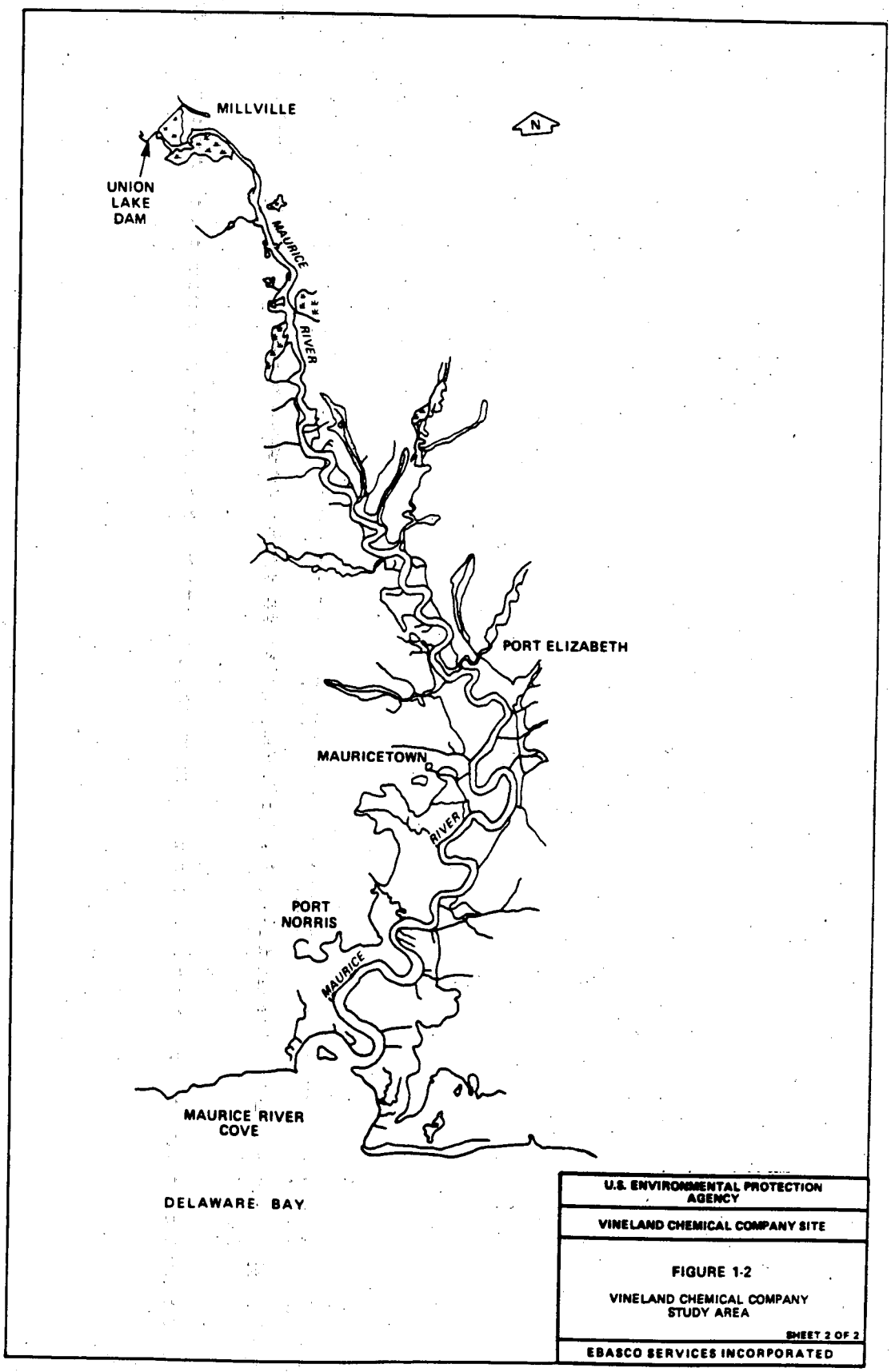


U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 1–1 VINELAND CHEMICAL COMPANY REGIONAL LOCATION MAP
EBASCO SERVICES INCORPORATED



1 1/2 0 1 MILE
0 1000 3000 5000 7000 FEET
1 5 0 1 KILOMETER
SCALE 1:24 000

U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 1-2 VINELAND CHEMICAL COMPANY SITE STUDY AREA SHEET 1 OF 2
EBASCO SERVICES INCORPORATED


MILLVILLE
N
UNION LAKE DAM
MAURICE RIVER
PORT ELIZABETH
MAURICETOWN
RIVER
PORT NORRIS
MAURICE
MAURICE RIVER COVE
DELAWARE BAY
U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 1-2
VINELAND CHEMICAL COMPANY STUDY AREA
SHEET 2 OF 2
EBASCO SERVICES INCORPORATED
SCALE 1 24 000

1.2 BACKGROUND INFORMATION

1.2.1 Site Description

The ViChem plant is located in a residential/ industrial area in the northwest corner of the City of Vineland in Cumberland County, New Jersey. The plant location is shown in Figure 1-3.

The plant is bordered on the north by Wheat Road and the Blackwater Branch, a tributary of the Maurice River. Residential areas border the plant to the east and south along Orchard, Oak and Mill Roads, as shown in Figure 1-4.

ViChem has produced organic herbicides and fungicides at this location since approximately 1949. ViChem currently produces two major herbicidal chemicals, disodium methanearsonate and monosodium methanearsonate. Table 1-2 lists chemicals used, manufactured, or known to be stored at the ViChem plant.

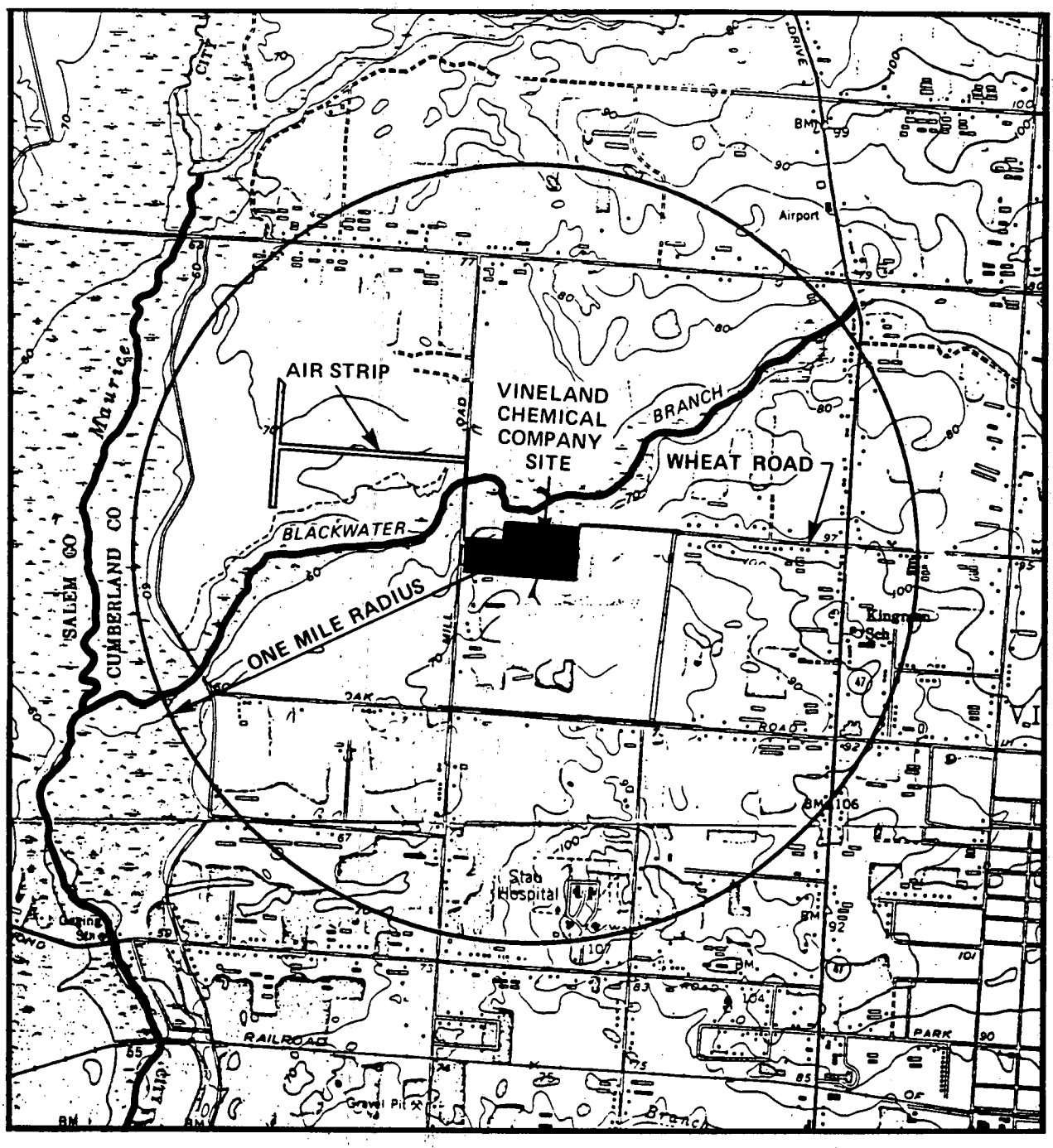
The ViChem plant site is shown in Figure 1-5. The plant consists of several manufacturing and storage buildings, a laboratory, a worker change facility, a wastewater treatment plant and several lagoons. The manufacturing and parking areas shown in Figure 1-5 are paved. The lagoon area is unpaved and devoid of vegetation. This area is dominated by loose sandy soils. The remainder of the site is covered by trees, grass, or shrubs.

The site is situated in a residential/industrial area. Twelve residences are shown in Figure 1-5 in the immediate vicinity of the plant. A number of other residences are located close to the plant along Wheat, Orchard, Oak, and Mill Roads as shown in Figure 1-4.

The Martex Manufacturing facility is located immediately north and west of the ViChem lagoon area. Martex reportedly produces packaging materials, although little information is available on the materials used or manufactured at this site.

The Blackwater Branch is immediately north of the ViChem plant site, as shown in Figure 1-6. This stream flows east to west and discharges into the Maurice River approximately 1.5 river miles downstream from the plant. The upper Maurice River, shown in Figure 1-2, then flows approximately seven river miles downstream into Union Lake, which is approximately two miles long. The Maurice River then flows approximately 25 river miles downstream from the Union Lake into the Delaware Bay, as shown in Figure 1-2.

Some time between April 1985 and June 1986, beavers constructed a dam on the Blackwater Branch just downstream from the Mill Road bridge. The dam flooded the Blackwater Branch to the approximate extent shown in Figure 1-5. The dam was removed in October 1987 to allow for construction of a new bridge. The Blackwater Branch is now flowing in its normal channel and the flooded areas have been drained.

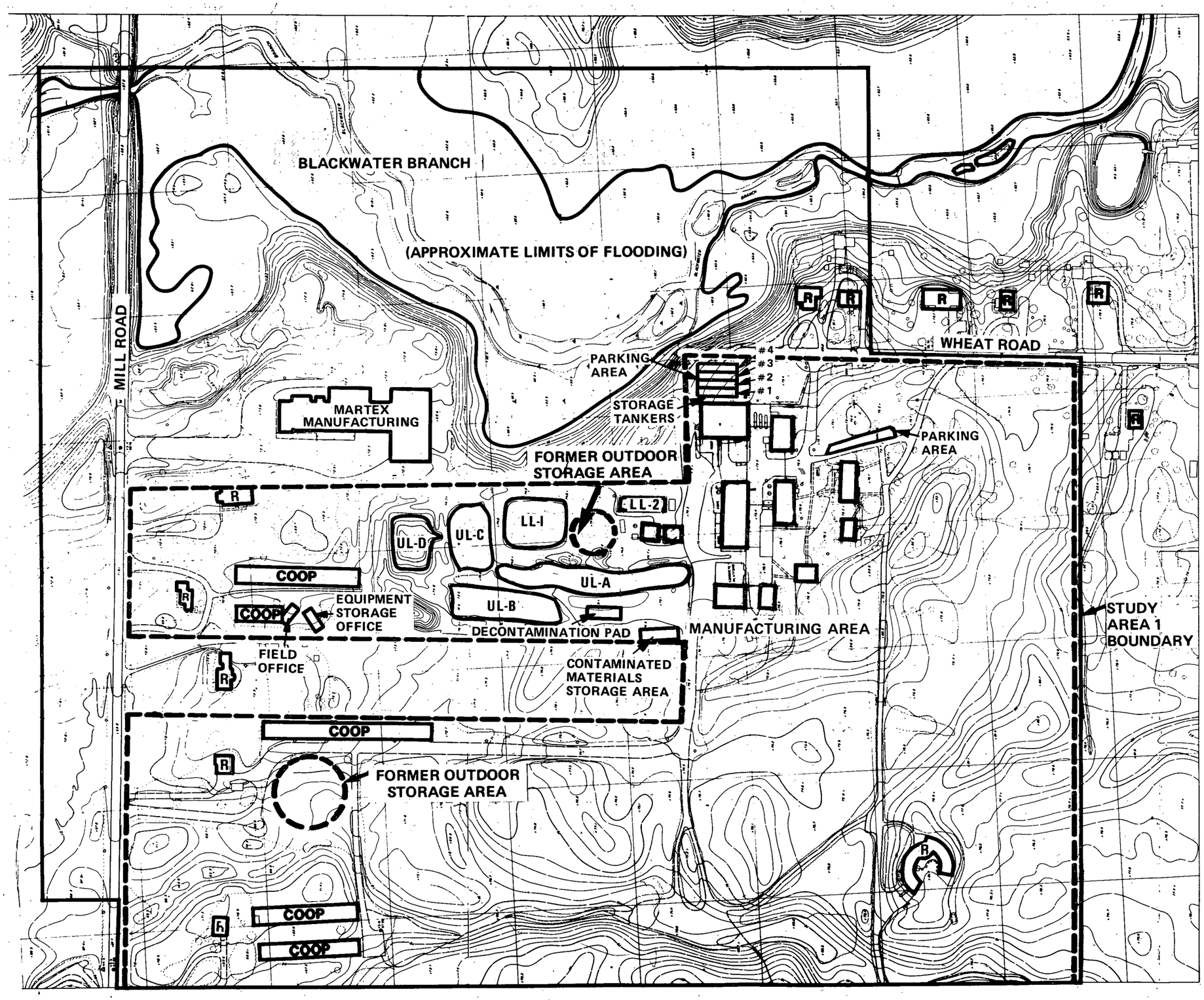


SCALE 1:24000

0 1 MILE

BASE MAP PREPARED BY U.S.G.S., 1977

U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 1-3 VINELAND CHEMICAL COMPANY ONE MILE RADIUS
EBASCO SERVICES INCORPORATED



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U.S. ENVIRONMENTAL PROTECTION AGENCY

VINELAND CHEMICAL COMPANY SITE

FIGURE 1–5

VINELAND CHEMICAL COMPANY SITE PLAN

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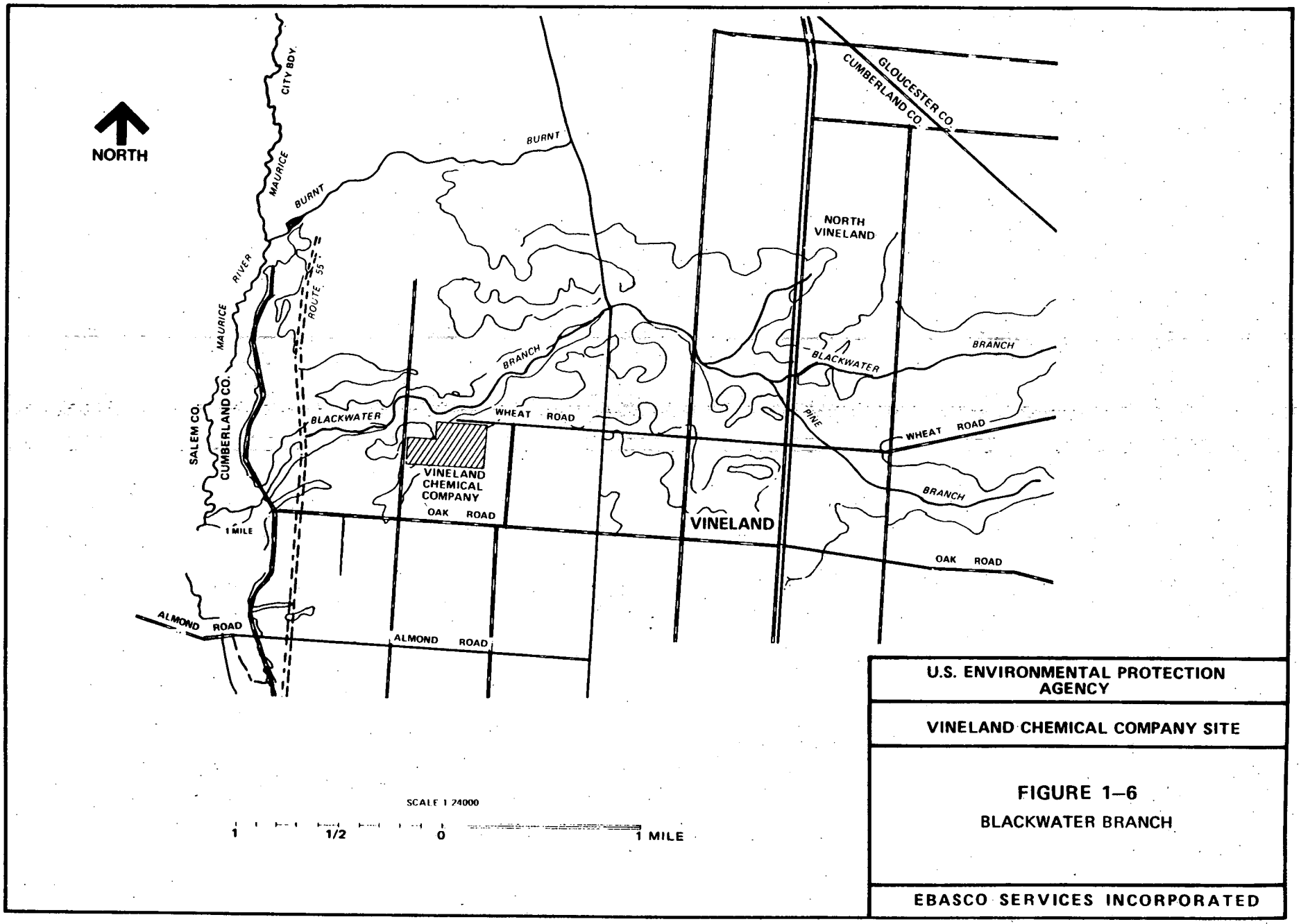

U.S. ENVIRONMENTAL PROTECTION AGENCY

VINELAND CHEMICAL COMPANY SITE

FIGURE 1–6

BLACKWATER BRANCH

EBASCO SERVICES INCORPORATED

TABLE 1-2

CHEMICALS USED, MANUFACTURED OR STORED AT VINELAND CHEMICAL COMPANY PLANT

INORGANIC METALS AND SALTS

Arsenic
Mercury
Mercury (II) chloride
Mercury (I) chloride
Cadmium
Cadmium Chloride

FLOCCULANTS

Aluminum
Iron

METAL ORGANIC ARSENIC COMPOUNDS

Disodium methane arsonate
Dodecyl and octylammonium methane-arsonate
Monosodium acid methane arsonate
Calcium acid methane-arsonate
Dimethylarsonic acid (Cacodylic acid)

ORGANIC MERCURY COMPOUNDS

Phenyl mercury dimethyldithiocarbamate
Phenyl mercuric acetate

HERBICIDES

Sodium 2,4-dichlorophenoxy acetate
2-4-dichlorophenoxy acetic acid (2,4D)
2(4-chloro-2-methyl phenoxy) propanoic acid (MCPP)

bis(dimethylthio-carbonyl)disulfide (thiram)

1,4-bis (bromoacetoxy)-2-butene
2,3-dibromopropionaldehyde

Alkylarylpolyether alcohol

SOLVENTS AND GENERAL ORGANIC CHEMICALS

Benzyl alcohol
Xylene
2,3 Benzofuran

Methanol
Epichlorolydrin
Acrolein
Isopropyl alcohol

Methyl chloride
Methylene chloride
Trichloroethane
Trichloroethylene

Tetrachloroethylene
Bromochloromethane

Methylene-bis-thiocymate
Hydrobromic acid

Tetrabutyl ammonium bromide
Bromo acetic acid

TABLE 1-2 (Cont'd)

CHEMICALS USED, MANUFACTURED OR STORED AT VINELAND CHEMICAL COMPANY PLANT

SOLVENTS AND GENERAL ORGANIC CHEMICALS (Cont'd)

Glycerine
Triton X-100
Formaldehyde
Butanediol

Gasoline
Kerosene

POSSIBLE CHEMICAL FROM MANUFACTURING

Phenol
Chlorophenols
Chloroacetic acid
Chlorides
Arsenic Trioxide
Arsenic Pentoxide
Methyl chloride
Methanol
Sodium hydroxide
Calcium oxides, chlorides, sulfates
Mercury Oxides
Cadmium Salts

Compiled from
1) Miller, F., NJDEP Memo, Vineland Chemical Ground Water Pollution Problem, 24 May 1985
2) Siting, M., Pesticide Manufacturing and Toxic Materials Control Encyclopedia, Noyes Data Corp., Park Ridge, NJ (1980)

A wastewater treatment system is in operation at the ViChem plant. The system has a design capacity of approximately 25 gallons per minute (gpm), or 36,000 gallons per day (gpd) assuming 24 hours of operation. The system was designed to treat between 2,000 and 5,000 gpd of process water, 20,000 gpd of groundwater that was to be pumped from the shallow water table, and storm runoff water as necessary. In addition, provisions were made to collect up to 60,000 gpd of non-contact cooling water in the event that a mechanical breakdown occurred and mixed the non-contact cooling water with the contaminated process water.

The wastewater treatment system consists of mix tanks, a reactivator, filters and ancillary equipment. Ferric chloride is added to the first mix tank and caustic soda is added to the second mix tank to promote flocculation. The wastewater then enters the reactivator where it is mixed with a polymer. This mixture then passes through a flocculation compartment where the large particles settle to the bottom and are removed to a rubber-lined tank. The reactivator effluent is polished by a tertiary filter before discharge. The slurry in the rubber-lined tank is pumped into a vacuum filter and the dry solids are deposited in a dumpster for off-site disposal. Any liquid not meeting discharge requirements is reportedly recirculated for treatment.

Some of the lagoons shown in Figure 1-5 are used in the wastewater treatment system. Lagoon LL-1 is a lined lagoon with a 490,000 gallon capacity. This lagoon was designed to hold process water, groundwater, and storm water as necessary prior to treatment. Water can be pumped from this lagoon to the wastewater treatment plant at 25 gpm. Lagoon LL-2 is also a lined lagoon, but it has a concrete base. It was previously used to store the arsenic-contaminated waste salt K 031 produced as a by-product of the herbicide manufacturing process, and later was used to hold the treatment plant sludge prior to disposal. It now holds water to be recirculated for treatment. Lagoon UL-A is an unlined lagoon. This lagoon receives the non-contact cooling water and the treated discharge from the treatment plant. Because the site soils are sandy and this lagoon is unlined, water in the lagoon rapidly infiltrates the groundwater.

The remaining lagoons shown in Figure 1-5, UL-B, UL-C, and UL-D, are all unlined and are not currently used in the water treatment system. However, aerial photographs provided by the USEPA's Environmental Photographic Information Center (EPIC) used in the USEPA's Site Analysis, Vineland Chemical Company (March 1988) show that UL-A, UL-B, UL-C, UL-D and LL-1 (which was previously unlined) were connected to one another in the past. The photographs show that all of the lagoons were filled with liquid.

The two lined lagoons, LL-1 and LL-2, are regulated by RCRA. The wastewater treatment plant and the unlined lagoon, UL-A, are regulated under the NJPDES program. Other active solid waste management units at the plant site include: trailers/tote bins used to store the K 031 waste salts and the treatment plant sludge; a septic system and leachfield; and the soil beneath the floors of the production buildings, where past operating procedures reportedly produced spillage. Inactive/abandoned solid waste management units are basically areas where waste salts were improperly stored in the past, including the waste salt piles, sludge piles, chicken coops, and outdoor drum storage areas.

The treatment plant was designed to produce an effluent with an arsenic concentration of 0.05 milligrams per liter (mg/l). ViChem initially had difficulties achieving this level. An interim standard of 0.7 mg/l was therefore agreed to and ordered by the NJDEP in December 22, 1981, with the understanding that the 0.05 mg/l level would eventually be met. In-house analytical results performed by ViChem on a daily basis indicate that the effluent has been reduced below the interim standard, but the levels are still greater than 0.05 mg/l at times. The levels are still greater than 0.05 mg/l when the influent concentrations are high, but are less than 0.05 mg/l when the influent concentrations are low.

ViChem reports that it no longer treats either groundwater or process water. Reportedly all of the water used in manufacturing the herbicides is consumed by the process and is included as inherent moisture in the product. ViChem ceased pumping and treating groundwater in July 1987 with the consent of the NJDEP. One of the reasons the NJDEP allowed ViChem to stop pumping and treating groundwater was the NJDEP's concern that the treatment plant effluent, whatever its arsenic concentration, would cause a groundwater mound, driving existing contamination deeper into the groundwater and promoting off-site migration. The wastewater treatment plant now reportedly treats only storm water runoff on an intermittent basis.

The herbicide manufacturing process produces approximately 1,107 tons of waste by-product salts each year. These salts have an EPA hazardous waste number of K 031 and are neither treated nor disposed of at the site, nor stored on-site for more than 90 days. The salts are transported by licensed shippers to licensed facilities in Ohio and Michigan for disposal.

1.2.2 Site History

ViChem began manufacturing organic arsenical herbicides and fungicides at this plant in approximately 1949. In addition to arsenical herbicides, the company also produced cadmium-based herbicides and used other inorganics such as lead and mercury. Table 1-2 presented a list of chemicals used, manufactured, or stored at the ViChem plant.

As early as 1966, the NJDEP observed ViChem discharging untreated wastewaters with unacceptable arsenic concentrations (67 mg/l) into the unlined lagoons. An unknown quantity of arsenic rapidly infiltrated into the groundwater from the lagoons. On February 8, 1971, ViChem was ordered to install and provide industrial wastewater treatment and/or disposal facilities. The wastewater treatment works did not become operational until March 1980.

Waste salts from the herbicide production process were stored on-site in uncontrolled piles on the soil, in the concrete lagoon LL-2 (which at the time was unlined), and in abandoned chicken coops on the plant property. The storage of salts in piles was observed in April 1970 and in the coops in April 1973. It was not until 1978 and many court orders that the salts were containerized and removed. These salts reportedly contained one to two percent arsenic (RCRA Part B Permit Application, 1980). Since these salts have a high solubility, precipitation contacting these piles rapidly dissolved the salts and carried an unknown quantity of arsenic into the groundwater.

Between 1975 and 1976, ViChem was "fixating" the waste salts for disposal at the Kin-Buc Landfill. The process involved mixing the dried salts with ferric chloride and soda ash, reportedly reducing the solubility. The process was stopped in 1976 when the Kin-Buc Landfill voluntarily stopped accepting all chemical wastes, including the fixated salts. ViChem then resumed piling the untreated waste salts on the soil surface at the plant site.

A court order issued on January 26, 1977 required ViChem to containerize the waste salts from the chicken coops and piles, then store the drums in a warehouse off-site. In June 1979, another order was issued for the disposal of the stored drums in an approved landfill. Removal and disposal of these drums was not completed until June 30, 1982.

Currently, the waste salts and the sludge from the wastewater treatment system are stored in large-capacity trailers and tote bins. The tote bins are filled at the point of generation in the manufacturing buildings and then emptied into the trailers. The NJDEP believes that releases are unlikely from this system. The salts and sludge are transported to the licensed facilities mentioned above. During peak production, as many as four to five trailers are filled and removed per week.

Aerial photographs provided by the EPA's Environmental Photographic Information Center (EPIC) and conversations with ViChem employees indicated several possible locations of past contamination. The cleared area in the southwest corner of the site shown as a "former outdoor storage area" in Figure 1-5 used to be occupied by two chicken coops. Sometime between November 1975 and March 1979, both coops were destroyed. These coops were reportedly used to store process chemicals and/or waste in the 1970s. The materials stored in the coops may have percolated into the groundwater. This area is now devoid of

vegetation. Photographs show many locations containing mounded material and/or drums. These were observed in the lagoon area and along the plant road. The waste salts were reportedly mounded so high at times in the lagoon LL-2 that the salts spilled over onto the soil in the lagoon area.

It is alleged that the floors of the manufacturing buildings have been leaking arsenic compounds into the underlying sands for years. The original floors of the buildings were brick and were allegedly in need of repairs several years ago. Allegedly, when the old bricks were removed, the soil contained crystalline waste from previous spills. It is not known whether the soils were removed when the floors were replaced, although in Ebasco's Phase II investigation the soils below building number 9 were sampled and had high arsenic concentrations as discussed in the Plant Site RI reports (Ebasco, 1989a). The floor of this building was solid and in good repair during Ebasco's 1987 investigation.

In response to a series of Administrative Consent Orders issued by the NJDEP, ViChem instituted some cleanup actions and modified the production process. The cleanup actions included stripping the surface soils in the manufacturing area, piling these soils in the clearing by well cluster EW-15, and paving the manufacturing area; installing a storm water runoff collection system; removing the piles of waste salts; and installing a groundwater pump and treat system including the wastewater treatment plant. Modifications to the production process included modifying the water system so that mixing of process water and non-contact cooling water was unlikely, lining two of the lagoons used in the wastewater treatment system (LL-1 and LL-2), and properly disposing of the waste salts off-site.

Evidence suggested that a serious groundwater contamination problem existed at the ViChem site and that the groundwater was discharging into the streams and degrading the downstream water quality. Therefore, this RI/FS was undertaken to investigate the extent of the soil and groundwater contamination and to evaluate remedial alternatives for rehabilitating the soil, groundwater, downstream sediments and surface waters.

1.2.3 Permit Actions

On December 2, 1985, the USEPA informed ViChem that its interim status for the lined RCRA impoundments was terminated as a matter of law on November 8, 1985 because of failure to comply with Section 3005(e)2 of RCRA. The USEPA determined that the company: (a) failed to certify compliance with the applicable financial assurance requirements for closure and post-closure care, (b) failed to certify that required liability insurance was ever actually obtained, and (c) failed to certify the preparation of a groundwater monitoring program meeting the requirements applicable to interim facilities. The company was to cease placing hazardous waste into the two lined lagoons.

ViChem submitted applications for RCRA and NJPDES permits. The RCRA permit application was for storage of hazardous wastewaters in the two lined lagoons. The NJPDES discharge to groundwater permit application was for discharge to the unlined lagoon UL-A.

In April 1986, the NJDEP advised ViChem of its intent to deny both the RCRA and NJPDES permits. The technical and administrative bases for the tentative decision to deny the permit are: (a) the discharge of 200,000 gallons per day (gpd) of non-contact cooling water into the unlined lagoons increased hydraulic gradients, thereby forcing contaminated groundwater deeper into the aquifer and further off-site; and (b) the treatment works were unable to meet the discharge criterion of 0.05 mg/l for arsenic. The technical bases for denying the RCRA permit application were inadequate closure, post-closure, and liability assurance requirements, and an inadequate groundwater monitoring program. The administrative basis for denial was the failure to submit a complete hazardous waste facility permit application given adequate time to do so. The NJPDES permit has been denied, but is being appealed by ViChem.

1.2.4 Previous Investigations

Since 1978, a number of studies have been performed by or for the NJDEP Office of Science and Research in the Maurice River watershed and at the ViChem plant site. ViChem itself has also conducted some investigations into the groundwater plume at the plant.

In 1979 and 1980, the NJDEP initiated a sampling program in the Blackwater Branch and the Maurice River downstream from the site. The results showed that the sediment arsenic concentrations in the Maurice River were the highest observed anywhere within the State of New Jersey. The study showed that the Almond Road weir, the submerged dam in Union Lake, the lower main dam in Union Lake, and the tidal creeks of the Maurice River estuary below Union Lake stored arsenic-contaminated sediments. Elevated arsenic concentrations were found in sediments as far from the site as the Delaware Bay, approximately 36 river miles downstream. Also, the arsenic concentration in the surface water decreased downstream from the site but did not reach the Federal Primary Drinking Water Standard for arsenic, 0.05 mg/l or 50 ug/l, until 26.5 river miles downstream from the ViChem site.

In 1978, ViChem commissioned a surface geophysical survey of the site at the direction of the NJDEP. The survey noted areas of probable contamination were the lagoon area, the area north of the lagoons to the Blackwater Branch, the former outdoor storage area shown in Figure 1-5, and along the plant road between the former outdoor storage area and the lagoons. The report also contended that the probable groundwater contamination was shallow and recommended locations for installing extraction wells.

In 1979, the NJDEP sampled soils in the ViChem plant area. Samples were taken at the surface and at depth. The study showed arsenic concentrations ranging from undetected to 864 mg/kg at various locations in the plant area.

In 1981, the NJDEP performed a surface geophysical survey of the plant area. The study identified two areas of probable groundwater contamination, one northwest of the lagoons toward the Blackwater Branch and the other near the former outdoor storage area. The study estimated that the probable maximum depth of the contaminant plume was approximately 40 feet.

In 1982, ViChem commissioned a groundwater investigation of the site. In this study, previous investigations were reviewed and a scheme to remove arsenic from the contaminated aquifer was pro- posed. This study included several sets of water quality data. Approximately 4 1/2 years of monthly arsenic concentrations at ViChem well MW-1 were presented along with data from ViChem wells MW-6 and MW-10. These data showed a marked drop in the arsenic concentration in the groundwater between 1978 and 1981. The study also presented monthly levels of arsenic in the Blackwater Branch at Mill Road, and in the Maurice River at the Almond Road weir. The study postulated that the arsenic load at Mill Road was very similar to the arsenic load at Almond Road, implying that the river system was essentially a conduit for arsenic transport into Union Lake. The study reviewed processes for arsenic cleanup at the site and recommended a groundwater pump and treat program along with controlled soil leaching.

In 1982, an employee of ViChem was diagnosed as having subacute arsenic poisoning. The New Jersey Department of Health then conducted a "Cross-Sectional Evaluation of Arsenic Exposure and Toxicity at the Vineland Chemical Company." The study revealed that employees had elevated arsenic concentrations in their hair and urine, but only exhibited minor symptoms associated with arsenic trioxide dust on the skin and mucous membranes. As a result of this survey, the arsenic handling practices in the production facility improved.

Two studies were conducted by the NJDEP and Rutgers University from 1980 to 1982 in Union Lake. The studies showed that Union Lake is chemically stratified during the summer. This stratification creates seasonal anaerobic conditions in the bottom sediments which are conducive to the formation of toxic arsenical compounds from the contaminated sediments (NJDEP, 1986). The Rutgers University work included sampling and analysis of water and sediments, as well as speciation of

arsenic [trivalent (As III), pentavalent (As V), monomethyl arsenic acid (MMAA) and dimethyl arsenic acid (DMAA)(Faust, 1983)]. This study concluded that the waters and bottom sediments were highly contaminated with substantial quantities of arsenic, and that total arsenic concentrations in all lake water samples exceeded the NJDEP and EPA drinking water standard of 50 ug/l. In sediments, the order of predominance of the four arsenic species (in descending order) was: As (V), As (III), MMAA, DMAA. In four of the sediments, the inorganic arsenate was between 73% and 88% of the total arsenical species. In water, the order of predominance was MMAA, As (III), As (V), DMAA. The results of the sampling efforts revealed a seasonal pattern of arsenic concentrations within the lake water with the greatest concentrations occurring during the summer. Additional NJDEP sediment sampling near the spillway area of Union Lake in April 1986 again showed arsenic contamination within the sediments and showed that contamination within the sediments was a surficial phenomenon.

In a 1983 to 1985 study by Rutgers University (Winka, 1985), it was shown that arsenic may exist in many species in the watershed and that these species may be transformed by changes in physical condition and season. Results indicated that within the water column the inorganic arsenic species may be one half of the total arsenic. Arsenic was not easily solubilized under aerobic conditions. The concern raised by these findings is that when an anaerobic condition developed on the bottom of Union Lake, the arsenic would be readily converted into the more toxic As (III) and As(V) forms. The more toxic forms could then be released to the water column upon seasonal turnover of the stratified layers. However, as these compounds are relatively insoluble, they are expected to precipitate back to the lake bottom within a relatively short period of time.

In 1982, ViChem commissioned a pumping test to be performed on the shallow aquifer underlying the lagoon area. The pumping test estimated a transmissivity in the shallow aquifer of approximately 50,000 gpd/ft, and a storage coefficient of between 0.1 and 0.04.

In 1985, ViChem's RCRA Part B permit application was submitted to the NJDEP. The application included a description of the wastewater and groundwater handling and a description of the wastewater treatment process and facility design. The application also included data on the production rate at the plant and the toxicity of the wastes generated. Arsenic concentrations in the Blackwater Branch through time were also presented.

In 1986, ViChem commissioned a pumping test to be performed in the deeper groundwater below the site. The plant's production well, screened from 130 to 165 feet below the ground, was used

as the pumping well and a deep monitoring well was installed in the lagoon area. The pumping test was conducted for 24 hours, with water levels measured in the deep monitoring well and several shallow monitoring wells near the discharge in the lagoon area. The report concluded that the "clay layer", reportedly encountered from 120 to 135 feet below the ground and which the production well is screened below, acts as a confining layer and prevents downward migration from the overlying aquifer. However, Ebasco's review of this pumping test data revealed that there was significant leakage across this "clay layer" during the pumping test.

The USEPA's Environmental Photographic Information Center (EPIC) produced a report in March 1988 on the ViChem site. The report presents an aerial photographic analysis of the ViChem plant and surrounding area. The first photograph presented was taken in March 1951 and the last was taken in November 1987. A total of 11 photographs are presented.

Among other things, the analysis of the photographs shows areas of "Vegetation Damage" and "Vegetation Stress" along the Blackwater Branch beginning with a September 1979 photograph. None of the prior photographs show vegetation damage or stress, and all of the later photographs show some vegetation damage and/or stress.

Some of the damaged areas are in the portion of the Blackwater Branch that was inundated with water from the beaver dam. However, the beaver dam was not constructed until some time after April 1985, much later than the first indication of vegetation damage/stress. A topographic base map for the site that was flown in April 1985 shows the Blackwater Branch flowing in its normal channel at that time. It should be pointed out that the damaged/stressed areas are coincident with the contaminated groundwater plume coming off the ViChem site.

In 1988, the USEPA's Environmental Response Branch prepared a bioassessment on the Blackwater Branch and the upper Maurice River. The report concluded that there was an adverse impact to the benthic communities in the Blackwater Branch downstream from the ViChem plant. The impact takes the form of lower species diversity and a toxic response in bioassay tests done with the sediments. The adverse impact on the Maurice River is less, however, probably resulting from dilution. This report is presented as an appendix to the River Areas RI report (Ebasco, 1989c).

In addition to the above studies, Ebasco, under contract with the USEPA, prepared RI reports for the ViChem plant area (Ebasco, 1989a) and for the river areas north and south of Union Lake (Ebasco, 1989c). Pertinent findings from these RI reports are as follows:

- There is a heavily contaminated arsenic plume in the shallow groundwater underneath the site within an aquifer termed the upper sand in the plant RI report. No arsenic contamination was seen below the base of the upper sand, ranging from 40 to 70 feet below the ground surface. A unit termed the banded zone, which contains clay laminae, was found at the base of the upper sand and apparently prevents the downward migration of arsenic.

- The groundwater in the upper sand discharges into the Blackwater Branch and, thus, provides the arsenic flux into this stream and the Maurice River.

- The arsenic flux in the groundwater was estimated at 6 metric tons per year in 1987. It was estimated that a total of approximately 500 metric tons of arsenic has been transported off the site through time.

- The Blackwater Branch floodplain is contaminated with substantial quantities of arsenic. This area was previously inundated with floodwaters from the beaver dam. Since the dam was breached, the floodplain is now exposed. The exposed floodplain sediments contain very high arsenic concentrations in places (up to 4,000 mg/kg).

- The Blackwater Branch and the upper Maurice River basically behave as conduits, transferring arsenic from the plant site into Union Lake. The inventory of arsenic bound to the sediments was estimated to be approximately six metric tons. This arsenic was apparently bound to fines and organics in the sediments.

- Union Lake's sediments bind a substantial quantity of arsenic, an estimated 140 metric tons (approximately one-third of the arsenic released frm the site). The arsenic is probably tightly bound to fines and organics in the sediments. The controlling mechanism for the lake water's arsenic concentration was not clear. On one hand, the water concentration coming in, within, and going out of the lake was approximately the same. This suggests that the lake behaves as a conduit, transferring arsenic downstream. On the other hand, the lake water and sediments were in apparent equilibrium, based on their respective arsenic concentrations and a partition coefficient determined experimentally for Winka (1985).

- The Maurice River below Union Lake had elevated sediment and water arsenic concentrations. The water arsenic concentration did not fall below 50 ug/l until approximately 10 miles downstream from the lake (26.5

miles downstream from the plant). The water concentration dropped sharply when the tidal front was reached. The arsenic inventory in the sediments could not be determined; however, it was estimated that possibly as much as half of the arsenic released from the site was stored in the lower Maurice River sediments.

- It was estimated that if the source of arsenic into the watershed (groundwater discharge off of the ViChem plant) were stopped, the water arsenic concentration in the Blackwater Branch and the upper Maurice River would drop relatively quickly. These portions of the watershed are believed to act as conduits for the arsenic flux and do not bind substantial quantities of arsenic relative to the lake. It was also estimated that if the source of arsenic were eliminated the lake water's arsenic concentration would drop, although how much and how quickly was not known. Arsenic may continue to desorb off of the sediments and maintain a somewhat elevated arsenic concentration in the future. At a minimum the concentration should not increase over what is present now and the present concentration is close to the MCL of 50 ug/l.

1.2.5 Community Concerns

In 1984, after the ViChem site was added to the National Priorities List, EPA implemented a community relations program to inform area residents about the Superfund related activities and obtain their input. Community concern increased from moderate to relatively high and also became more specific. The involvement of organized environmental groups generated media attention and increased public awareness of the site.

As a result of the EPA's community relations activities, five major community concerns were identified:

- Human health risks from exposure to contaminated groundwater because some of the residents relied on groundwater for potable water;
- Human health risks from exposure to contaminated surface water because local rivers and lakes are used for recreation;
- Frustration over the perceived lack of remedial action at the site;
- A perceived lack of cooperation on behalf of ViChem during the remedial response process; and
- A perception of inadequate information from the NJDEP.

1.3 REMEDIAL INVESTIGATION STUDY

1.3.1 Initial Activities

The initial tasks of this Work Assignment were the development of a Work Plan Memorandum, a Work Plan, and a Field Operations Plan (for both Phases I and II) for the RI/FS. The Work Plan Memorandum presented the scope of the program and the estimated schedule and budget to perform these initial tasks.

Prior to the preparation of project plans, a site reconnaissance was performed to familiarize the investigators with the site, determine possible sampling locations, and obtain information for developing the Health and Safety Plan. Existing information and prior reports prepared by ViChem and the NJDEP were also reviewed. Following the site visit and the evaluation of the existing data, potential remedial alternatives were identified in order to scope out the field sampling and analyses program and to specify the appropriate levels of data quality required.

1.3.2 Field Investigation

Ebasco's Union Lake investigation was conducted in two phases. Phase I took place in June and July of 1986. Phase II took place in January 1987.

Phase I

The primary Phase I objective was to repeat the sampling at stations sampled by the NJDEP in 1979 and by Faust, et al., in 1983. Secondary objectives included: sampling at new locations to broaden the data base; developing a bathymetric contour map of Union Lake; estimating the spatial distribution of sediments within the Lake; and testing equipment and field procedures to plan the Phase II effort.

Twenty sediment and 31 water samples were collected from 24 locations in Union Lake. The water samples were analyzed for the following parameters:

- Dissolved and particulate arsenic (4 samples);
- Dissolved arsenic, particulate arsenic, and field water quality parameters including temperature, pH, Eh, dissolved oxygen, and specific conductance (13 samples);
- Hazardous Substance List (HSL) inorganics, HSL volatile organics (VOA), dissolved arsenic, particulate arsenic, and field water quality parameters (5 samples);

- HSL inorganics, HSL VOAs, dissolved arsenic, and particulate arsenic (1 sample); and
- Field water quality parameters (8 samples).

The sediment samples were analyzed as follows:

- Total organic carbon (TOC), total arsenic, and total iron (9 samples);
- TOC, total arsenic, total iron, HSL inorganics, and HSL VOAs (2 samples); and
- Grain size (9 samples).

The details of the Phase I investigation are presented in Section 4.

Phase II

The Phase II objective was to obtain supplemental data to characterize all possible exposure routes, including ingesting fish from Union Lake.

Twenty-two water and six fish samples were collected from 14 locations in the lake. Each of the water samples was analyzed for dissolved arsenic, HSL inorganics, and field water quality parameters. The fish samples were analyzed for total arsenic, pesticides, and PCBs.

All Phase II water samples were split with ViChem. ViChem personnel declined assisting in or observing the sampling process; however, ViChem provided sample bottles to Ebasco. Ebasco personnel filled the ViChem bottles with the appropriate sample aliquots. Ebasco logged and labelled the ViChem sample bottles. ViChem personnel returned periodically to Union Lake to pick up the filled sample bottles and logging documentation. ViChem declined receiving split samples of the fish collected during the field investigation.

The details of the Phase II investigation are presented in Section 4.

1.3.3 Bench-Scale Studies

Bench-scale treatability studies were performed to evaluate the feasibility of using several different treatment methodologies to treat arsenic-contaminated sediment.

A sediment fixation treatability study was performed to determine if arsenic could be chemically stabilized or physically bound to the sediment such that total arsenic concentrations in the leachates from the RCRA EP Toxicity test

and the Multiple Extraction Procedure (MEP) test were less than 5.0 mg/l. Also, the Unconfined Compressive Strength of the fixed product was designed to be at least 1,500 lbs/ft^2. These tests are described in Section 6.

A soil extraction treatability study was performed to determine if arsenic could be removed from the sediments to a concentration below 20 mg/kg. The target level of 20 mg/kg total arsenic was established at the inception of the study based on the New Jersey Environmental Cleanup Responsibility Act (ECRA) guidance for arsenic in soils. The extraction tests are described in Section 6.

The target levels for the sediment treatability studies (fixating the soils such that the leachable arsenic concentration was less than 5 mg/l and extracting arsenic such that the remaining arsenic concentration was less than 20 mg/kg), were established at the beginning of the study. It was believed that if these levels were achieved, the treated sediments would be suitable for disposal in a nonhazardous waste landfill. Subsequently, guidance has been received from EPA Region II, EPA Headquarters, and the NJDEP on the criteria for nonhazardous waste disposal of the treated sediments. These criteria are discussed in detail in the Union Lake FS report (Ebasco, 1989f).

1.3.4 Risk Assessment

A risk assessment was performed to estimate possible human health risks from exposure to Union Lake's sediment, water, and fish. The assessment was performed using the basic methodology described in the Superfund Public Health Evaluation Manual (USEPA, 1986b).

Exposure scenarios were developed considering that the lake is a popular recreational area. Risks were calculated on a worst case basis, using very conservative exposure assumptions and maximum contaminants levels, and on a most probable basis, using more realistic exposure assumptions and mean contaminant levels. The risk assessment is presented in Section 7.

1.4 OVERVIEW OF REMEDIAL INVESTIGATION REPORT

This RI report is comprised of eight sections. The Introduction, Section 1.0, provides background information regarding site location and physiography, facility history and operation, waste discharges, and community concerns. The nature and extent of the problem, as identified through previous studies, is presented in this section. A summary of the RI, identifying the activities of each major component is also provided.

Section 2.0, Site Features Investigation, presents a general description of Union Lake including information on demography, land use, natural resources, and climatology.

Section 3.0, Hazardous Substances Investigation, presents data from the previous investigations in Union Lake. Specifics about the contamination such as quantities, location and composition are included, as are contaminant characteristics relevant to potential biological and human health impacts.

Section 4.0, Surface Water and Sediment Investigation, presents the results of the sediment and surface water investigations and incorporates the findings of previous studies into a discussion of physical and chemical characteristics, contaminant transport, and considerations for remedial alternatives.

Section 5.0, Biota Investigation, presents the findings of the biota investigation. The existing contamination levels in the resident fish are discussed.

Section 6.0, Bench-Scale Treatability Studies, contains a description of the bench-scale studies performed to evaluate the feasibility of potential technologies for remedial action. The objective(s), description, results and conclusions for each test are presented.

Section 7.0, Public Health and Environmental Concerns, presents the risk assessment for public exposure to the lake's sediment, water, and fish. Calculations of the risks at various sediment arsenic concentrations are also presented to aid in identifying remedial alternatives for the lake's sediment.

Section 8.0, Summary of the Remedial Investigation, summarizes the RI report.

The References section presents the previous studies cited in this document, as well as other documents used to conduct and prepare this RI.

The RI report contains the following four appendices:

Appendix A is a list of the flora and fauna observed in the Union Lake area. Both the scientific and common name of each plant and animal are provided in this appendix.

Appendix B is the laboratory report of the arsenic fixation in the sediment treatability study. Sample preparation procedures and results of the analyses are presented in this appendix.

Appendix C is the laboratory report of the treatability study for the extraction of arsenic from sediment.

Appendix D is the Field Water Quality Results table.

2.0 SITE FEATURES INVESTIGATION

This section presents site features or elements specifically applicable to remedial alternatives being considered for Union Lake. General site demographics, land use, natural resources, climatology, and cultural resources are presented.

2.1 DESCRIPTION OF THE UNION LAKE STUDY AREA

The Union Lake dam went under construction in 1866 and was completed in 1868. The earthen dam is approximately 2,000 feet long and 24 feet high. At the time of construction, the lake was the largest manmade lake in the country. The lake was developed privately, and was sold to the New Jersey Department of Environmental Protection in 1982 under the Green Acres Program.

The total surface area of Union Lake is approximately 870 acres at its normal pool elevation of 27 feet above mean sea level (MSL) (PRC Engineers, 1986). Union Lake is typically shallow (less than 15 feet deep), particularly within the northern two-thirds of the lake as shown in Figure 2-1. The greatest depth of the lake, approximately 25 feet, occurs adjacent to the dam's spillway at the southern end of the lake. At the northern end of the lake, remnants of a nineteenth century dam are evident with a deep hole (approximately 20 feet deep) present on the southern side of this submerged structure. The deep hole was probably caused by overflow over the submerged dam.

The surrounding lake shore is a predominantly coniferous forest with sandy soils. Approximately 25 private residences and a tennis and sailing club are situated on the eastern shore of the lake. A swimming beach and recreational area are adjacent to the dam at the southern end of the lake on the eastern shore. The town of Millville is just south and slightly east of the lake. The city of Vineland is approximately 3 miles north and east of the northern end of the lake. The western shore of the lake is uninhabited. Several small islands are situated close to the western shore.

The dam at the southern end of the lake has been assessed to present a high hazard due to a severely inadequate spillway capacity and embankment stability. Construction activities are currently underway to demolish the existing spillway and reconstruct a new auxiliary spillway and downstream channel. This work has required a partial controlled breaching of the dam and lowering of the lake water level. The pool elevation was lowered by approximately eight to nine feet resulting in the exposure of 50 to 105 acres of lake sediment (see Figure 2-2), particularly within the northwestern, northern and northeastern sections of Union Lake (PRC Engineers, 1986).

2.2 DEMOGRAPHICS

Union Lake is located in the City of Millville, Cumberland County, New Jersey. Millville is the second largest city in the

N 206000
N 208000
N 210000
N 212000
N 214000
N 216000
N 218000
N 220000
E 1886000
E 1888000
E 1890000
E 1892000
REFERENCE STATION 4
REFERENCE STATION 1
REFERENCE STATION 2
STREAM CHANNEL
SUBMERGED DAM
PUBLIC BEACH
5'
10'
15'
20'
0 400 800 1600
SCALE IN FEET
LEGEND
—10'— BATHYMETRIC CONTOUR
VINELAND CHEMICAL COMPANY SITE - UNION LAKE
FIGURE 2-1
UNION LAKE BATHYMETRY
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N 206000
N 208000
N 210000
N 212000
N 214000
N 216000
N 218000
N 220000

E 1896000
E 1894000
E 1892000

PUBLIC BEACH

ESTIMATED POOL SIZE AT THE DRAWDOWN CONDITION

0 400 800 1200
SCALE IN FEET

VINELAND CHEMICAL COMPANY SITE - UNION LAKE

FIGURE 2-2
UNION LAKE ESTIMATED POOL SIZE AT THE DRAW DOWN CONDITION

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Vineland-Bridgeton-Millville Standard Metropolitan Statistical Area (SMSA). The City of Millville encompasses a total of 44.3 square miles and has a population of 24,815 (U.S. Bureau of the Census, 1980). This represents a 13.9% increase in population over the 1970 census. According to projections by the New Jersey State Department of Labor, the population of Millville is expected to increase by approximately 21.5% to 30,147 by the year 2000. This projection indicates a moderate growth scenario throughout the next 12 years.

2.3 LAND USE

Millville is classified by the New Jersey Division of State and Regional Planning as an urban center/rural community. Over 75% of the city's land is undeveloped, with 60% of the total land area dedicated to woodlands. The Millville area is essentially a flat plain with topographic variations from ten to one hundred feet above mean sea level (MSL).

Union Lake is situated in the northeast quadrant of the city of Millville and is almost entirely surrounded by coniferous forest, woodland, and open space. Soils are predominately sandy. The most notable exception to this pattern of land use is a 110-unit, medium-density residential development on the eastern central shore. The lake is a component of the Maurice River drainage system, an impoundment of the river located approximately 25 miles upstream from the confluence with the Delaware Bay. Most of the land adjacent to the Maurice River, from Union Lake to the southernmost reaches of the river within the Millville city limits, is classified as wetlands and is included in the boundaries established by the State of New Jersey Coastal Area Facilities Review Act (CAFRA). Wetland classifications do not extend north of the Union Lake Dam.

Land use in the vicinity of Union Lake focuses primarily on recreational activities including hunting, fishing, boating and hiking. A significant portion of the land surrounding the lake is zoned LC (Land Conservation Zoning District) and is protected as recreational land under the State of New Jersey Green Acres Program. The Green Acres Program is administered by the NJDEP and provides for the purchase of lands which are developed as public recreational facilities.

Other land use zone districts immediately adjacent to Union Lake include R-15 (Residential, minimum lot size 15,000 sq.ft.), R-10 (Residential, minimum lot size 10,000 sq.ft), and I-1 (General Industry). The R-15 zone districts include the developed residential area on the eastern shore of the lake and the southwest portion of the lakeshore east of Carmel Road. The R-10 and I-1 zone districts are located at the extreme southern portion of the lake, adjacent to Union Lake Dam.

Union Lake provides a multitude of recreational opportunities. The Union Lake Tennis and Sailing Club operates a facility used by approximately 200 families. The City of Millville manages Union Lake Park, which provides public access to lake-related activities such as canoeing, fishing, and boat rental. Numerous trails around the perimeter of the lake provide public access to extensive areas for picnicking, bicycling, hiking, and horseback riding. The northern end of the lake offers large, undisturbed areas which are suitable for hunting, fishing, trapping and nature study.

General information on the usage of Union Lake was obtained from the Millville Parks Department (Romanick, R. 1988). The beach area at the southern end of the lake is approximately 400 feet long fronting the water and approximately 100 feet wide. The swimming season runs from June through August, when a lifeguard is on duty on the beach for 8 hours per day. The Parks Department estimates that a maximum of 400 people would use the beach on a hot day. Swimming is not restricted at other times, however the Parks Department estimates that there is not a significant amount of off-hour swimming. The lake is widely used for sailing and fishing. Sailing is seasonal, while fishing occurs year-round except when the lake is frozen. The Parks Department estimates there would be a maximum of 12 sailing boats and 12 fishing boats using the lake at one time during good weather.

The area around Union Lake is seen by the City of Millville as having minimal potential for future development; however, lands extending to approximately mid-lake along the eastern shore, and to a lesser extent, along the western shore, have been classified as areas for potential development of medium density residential uses.

The City of Millville is served by three principal arterials (NJ State Routes 47, 49 and 55). These roads connect with other major and minor arterials and collectors within the city to serve the entire Millville area, and provide major surface transportation links to other major north-south transportation corridors and the Philadelphia/Camden region.

Rail service is provided by the Pennsylvania/Reading Seashore Lines. Limited private and commercial air service is provided by the Millville Airport, located southwest of the Millville central business district.

2.4 NATURAL RESOURCES

Union Lake is the largest lake in southern New Jersey. Located on the outskirts of Millville at an elevation of 27 feet MSL, the lake has a surface area of 870 acres, a maximum depth of 25 feet, and a mean depth of nine feet.

The shoreline consists of 85% woodland, 5% parkland, and 10% brush and swamp. Much of the shoreline is lined with sedges (Scirpus sp.) while the dominant submerged aquatic is bladderwort (Utricularia sp.). The littoral, or shallow area, is composed of 80% sand, 5% rock, 5% gravel, and 10% muck and debris. The plants and animals observed and/or recorded in the Union Lake area are listed in Appendix A.

2.5 CLIMATOLOGY

Available climatological data were obtained from cooperative weather stations maintained by the National Weather Service, located in Vineland (precipitation and wind) and Bridgeton (temperature). The Vineland station had accumulated data since 1885, while the Bridgeton station had data dating back to 1894. Both of these stations have subsequently been abandoned, with a station in Millville now providing local climatological data.

Vineland receives approximately 45 inches of rainfall per year. Monthly averages range from 3.46 inches in April to 5.21 inches in August. During an average year, Vineland can expect 77 days when precipitation will exceed 0.1 inches, with 30 of those days exceeding 0.5 inches. Mean snowfall amounts to 18.6 inches with the maximum occurring in February (6.4 inches).

No temperature data are available for Vineland proper, but Bridgeton (12 miles WSW of Vineland) has a mean annual temperature of 54.7 degrees Fahrenheit. The mean maximum and minimum annual temperatures are 65.0 and 44.6 degrees Fahrenheit, respectively. The highest temperature recorded was 104 degrees Fahrenheit, and the lowest temperature was -12 degrees Fahrenheit. The average growing season is 170 days and the average date of the last and first killing frosts are April 15, and October 25, respectively.

Although detailed wind information is not available for the site, from October through April the predominant wind flow is from the northwest. From May through August the dominant flow is out of the southwest. During September the wind is from the southeast.

2.6 CULTURAL RESOURCES

The Union Lake area is home to several sites with cultural and archaeological significance. Artifacts that have been discovered along the shore are described below.

Along the northeastern shore of Union Lake many artifacts have been found, including: stemmed, notched, and triangular projectile points; a pick-shaped bannerstone or atlatl weight; a small whetstone; several hundred cord-marked and fabric-impressed sherds; various rough stone objects (no recognizable tools); a slate pendant; and various utilized flakes and scrapers. A small prehistoric hearth containing

stone chips and potsherds was also found. In addition, the Union House (now a museum) located on the northeastern shore of Union Lake was built in 1728 as a stagecoach rest stop. The structure is classified by the State of New Jersey as one of the oldest homes in the state and is listed on the Cumberland County Historical Register.

Cultural remains have been found along the western shore and on two small islands near the western shore. These remains include stemmed, notched and triangular points; a few potsherds of cord-marked and fabric impressed varieties; a fragmentary sandstone slab whetstone; and various chipping debris as well as utilized flakes and a cylindrical pestle.

Along the western shore of Union Lake on the point of land between the Lebanon Branch on the south and an unnamed stream on the north, finds have been made including stemmed, notched convex-base and triangular projectile points; a few cord-marked sherds; thumbnail scrapers; and various artifacts of European manufacture including a kaolin pipe bowl and metal buttons.

Artifacts have been found on two large and two small islands located adjacent to the western shore of Union Lake just south of Lebanon Branch. The artifact inventory includes various stemmed and notched points; sherds of cord-marked vessels; and a few rough stone objects and chips. Twenty-three sherds of a single cord-marked vessel were found, apparently in situ, on the northern end of the largest island.

Two kaolin pipe stems and a badly weathered Lincoln-head cent were the only artifacts discovered on the point of land near the southeast corner of the lake, in the vicinity of Luna Park.

Artifacts discovered at the above locations are representative of a span of prehistory in the southern New Jersey area beginning no later than the Late Archaic stage (C-2500-1300 B.C.) but possibly considerably earlier. There is some suggestion of very early occupations in the Union Lake area. The discovery of artifacts at Loci I, II, III and IV are suggestive, though not conclusive, of occupations dating to 600 B.C.

2.7 DAM RECONSTRUCTION

The dam at the southern end of Union Lake is currently undergoing reconstruction. The dam was assessed to pose a safety hazard because the spillway was inadequate to pass the Probable Maximum Flow (PMF) resulting from various rainfall events. The firm of PRC Engineers is the design engineering firm for the dam reconstruction project. PRC provided the specifications of the reconstruction project (PRC Engineering, 1986).

The spillway in the dam was approximately 200 feet wide. The spillway had an adjustable lip which could be varied between elevations 24.5 and 26 feet MSL. In addition there was an outlet canal at the eastern end of the dam at elevation 21 feet MSL which leads to a turbine owned by WA WA, Inc. The canal and turbine could be used, if desired, to generate power. This canal is not in use and will not be affected by the reconstruction project.

Prior to the reconstruction project, the lake's normal pool elevation was approximately 27 feet MSL. This elevation varied with the flow magnitude out of the lake, with greater flows producing a greater depth of spillway overflow and higher pool elevations. PRC estimates that the median flow out of the lake is 325 CFS (experienced 50% of the time), which produces the normal pool elevation of 27 feet.

To facilitate the dam rehabilitation, a section of the spillway approximately 32 feet wide was breached to lower the lake's water level. The breached section has a bottom elevation of approximately 16 feet MSL. The depth of water flow over the breached section of the spillway is approximately 2.2 feet at the median 325 CFS flow, resulting in a pool elevation of approximately 18.2 feet MSL. A flow of 500 CFS will result in a pool elevation of approximately 19 feet MSL. For estimating purposes, one can assume that the lake's water level has been lowered between 8 and 9 feet for the reconstruction, although the exact pool elevation at any time is a function of the outflow.

The reconstructed spillway will be 200 feet wide with an elevation of 26.67 feet MSL. A new auxiliary spillway 100 feet wide will be provided to pass high flows. In addition, six low level outlets will be installed, three at an elevation of 16 feet MSL and three at an elevation of 11 feet MSL. These low level outlets can be used to pass high flows or to artificially lower the lake's water level below the spillway elevation of 26.67 feet, if desired.

The NJDEP Division of Fish, Game, and Wildlife is the using agency for the reconstruction project and will control the operation of the dam spillway and low level outlets. They can, if desired, lower the water level below the spillway using the low level outlets. This can be done, for example, if this agency decides to control bottom growth through partial draining of the lake to expose bottom areas, thus allowing the vegetation to freeze and die before refilling the lake.

2.8 SURFACE AND GROUNDWATER HYDROLOGY

Detailed studies of the lake's inflow versus the lake's outflow have not been performed. However, there is a USGS stream gaging station on the Maurice River at Norma, approximately six miles

upstream of Union Lake. The estimated outflow from Union Lake is approximately twice the flow of the Maurice River at Norma (PRC Engineering, 1986). For example, the median outflow from the lake is estimated to be 325 CFS, while the data from the Norma station shows an average flow rate of 168 CFS during the period of record from 1932 to the present.

The lake's outflow versus the inflow takes on significance when trying to estimate the effects of drought on the water level of Union Lake. While no historical records were found which described low lake water levels, historical data are available describing low flow of the Maurice River at the Norma gaging station.

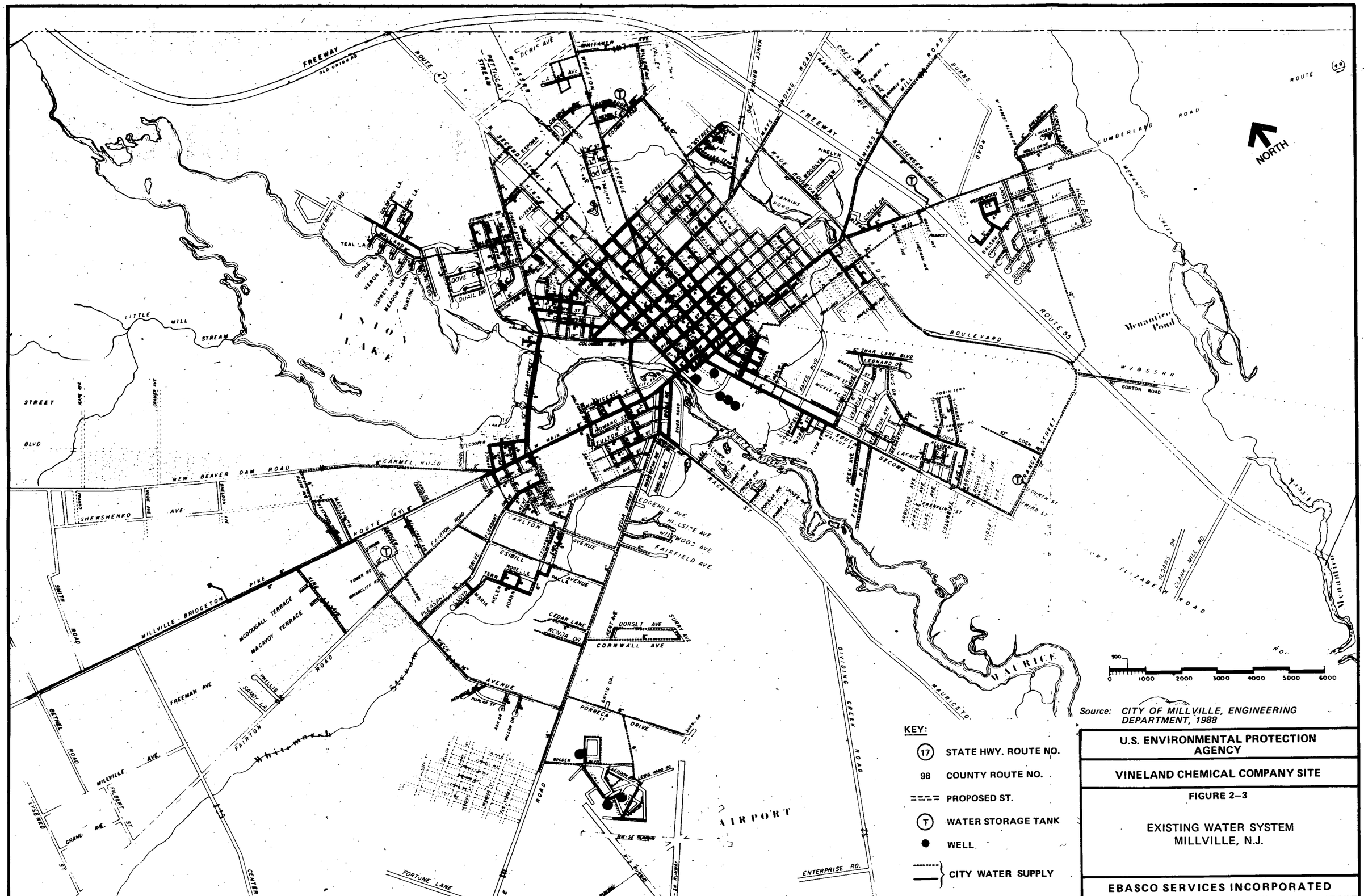
The minimum average daily flow recorded at Norma is 23 CFS, observed on September 8, 1964, July 2, September 7, and September 11-13, 1966. Assuming that the 2 to 1 flow ratio holds true, this low flow would produce a discharge out of the lake of approximately 45 CFS.

Assuming that there is discharge out of the lake, this would at least signify that the lake's water level would not drop below the top of the new spillway at elevation 26.67 feet. In other words, even under the low flow conditions observed since 1932, one can assume that the lake would still overflow the spillway and that the lake's pool elevation would approximate the normal 27 foot pool elevation.

There is little groundwater information available in the vicinity of Union Lake. It is known that the City of Millville derives its public water supply from 8 groundwater wells instead of from Union Lake. The locations of these wells are presented in Figure 2-3.

Seven of these wells are screened at approximately 100 feet below the ground surface while the eighth, one of the wells adjacent to the Maurice River shown in Figure 2-3, is screened at approximately 300 feet below the ground. These wells are all at least one mile away from Union Lake.

It is not known whether Union Lake is influent or effluent, that is, whether the lake recharges the local groundwater or whether the local groundwater recharges the lake. However, the City of Millville does periodically monitor its public water distribution system for arsenic content. The monitoring has shown acceptable arsenic concentrations in the water supply system (Harris, J. 1988).



Source: CITY OF MILLVILLE, ENGINEERING DEPARTMENT, 1988

KEY:

- (17) STATE HWY. ROUTE NO.
- 98 COUNTY ROUTE NO.
- PROPOSED ST.
- (T) WATER STORAGE TANK
- WELL
- CITY WATER SUPPLY

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VINELAND CHEMICAL COMPANY SITE

FIGURE 2–3

EXISTING WATER SYSTEM
MILLVILLE, N.J.

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3.0 HAZARDOUS SUBSTANCES INVESTIGATION

This chapter discusses the quantities, location, components and composition of hazardous substances found in Union Lake. Sources of environmental contamination or potential public health threats are described along with data on the waste component characteristics, toxicity, bioaccumulation, metabolism and environmental transformations.

3.1 WASTE TYPES

Based on the results of the risk assessment (Section 7), it has been determined that the only hazardous substance of concern in Union Lake is arsenic, especially sediment bound arsenic. The arsenic contamination in the sediment is highly variable, with concentrations ranging from less than detectable levels to 1,273 mg/kg. The contamination is widespread across much of the lake bottom and tends to be a surficial phenomenon. Most of the arsenic is found in the top one or two feet of sediment. Although widespread, the arsenic concentrations are extremely heterogeneous. Samples in very close proximity vary greatly in arsenic concentration. Water arsenic concentrations, on the other hand, are low, and range from 10 to 187 ug/l. These results are based on samples taken in 1986 and 1987 by Ebasco and the NJDEP.

3.2 WASTE COMPONENT CHARACTERISTICS AND BEHAVIOR

3.2.1 Environmental Transport and Fate

Arsenic is ubiquitous in the earth's crust at low concentrations, generally below 5 mg/kg (USEPA, 1976). It occurs in four oxidation states: the -3 state, the metallic (0) state, and the +3 and +5 states. The metallic state can be found in certain types of mineral deposits, the +3 and +5 states are common in a variety of complex minerals and in dissolved salts in natural waters. The -3 state is present in gaseous AsH_3 (arsine). Arsenic occurs most frequently in nature in the pentavalent state as arsenate.

In soil, arsenic is present at concentrations from 0.1 mg/kg to more than 1000 mg/kg, depending on the soil's particular geological history (Erlich, H.L., 1981). Analysis of 1,577 U.S. surface waters showed arsenic to be present in 87 samples with concentrations ranging from 5 to 336 ug/l, and a mean level of 64 ug/l, (Kopp, J.F., 1969). In addition, large amounts of arsenic have been introduced into the environment in various chemical forms. Inorganic arsenic compounds such as sodium arsenite, lead arsenate and calcium arsenate have been used in agriculture; arsenic pentoxide is used as both a herbicide and a pesticide. Organic arsenic compounds such as monomethylarsenic

acid ($CH_3AsO(OH)_2$) and dimethylarsonic acid ($(CH_3)_2AsOOH$) (also known as cacodylic acid) and their salts have been widely used as herbicides and pesticides. In addition, smelting operations and coal burning power plants have been principal sources of arsenic emissions into the environment.

Arsenic is mobile in the environment. Both natural and manmade arsenic can be cycled within the air, water, and soil compartments by mechanisms such as oxidation/reduction, adsorption/desorption, precipitation/dissolution, and biological methylation and demethylation. Arsenic can also be taken in by plants and subsequently ingested by animals, and can be bioconcentrated by fish and other organisms from arsenic in the water column.

Aqueous Speciation

Arsenic occurs in natural waters as arsenate (+5), arsenite (+3) and methylated species. Arsenic acid (H_3AsO_4) and arsenious acid (H_3AsO_3) are formed from arsenate and arsenite, respectively. Arsenious acid is formed from the dissolution of arsenious trioxide in water, whereas arsenic acid is formed from the dissolution of arsenic pentoxide in water.

Under the pe (log standard oxidation-reduction potential) and pH conditions typical of natural surface waters, the arsenate species ($H_2AsO_4^-$ and $HAsO_4^{2-}$) predominate. Under moderately reducing (lower pe) aquatic conditions, the arsenite species H_3AsO_3 and $H_2AsO_3^-$ are likely to predominate.

Evidence suggests that the arsenite (+3) form of arsenic is four to ten times more soluble in soil (and probably sediment) pore waters than is the arsenate (+5) species (Deuel and Swoboda, 1972). This suggests that under reducing pore-water conditions, redox (oxidation-reduction) reactions may result in increases in aqueous phase total arsenic concentrations.

In addition to direct effects on the solubility of arsenic itself, reducing conditions may indirectly increase arsenic concentrations through the reduction of ferric (+3) to ferrous (+2) iron, and the accompanying dissolution of amorphous iron oxides. The importance of iron redox reactions to arsenic cycling (similar to that of phosphorus) has been postulated by a number of authors including Deuel and Swoboda (1972) and Ferguson and Gavis (1972).

Evidence indicates that aqueous speciation of arsenic is also controlled by biological methylation and demethylation. Biomethylation of arsenicals is generally thought to occur in the anaerobic environment of the sediment. McBride & Wolfe (1971) showed that an anaerobic bacterium, Methanobacterium strain M.O.H could methylate arsenic, and produced dimethylarsine (DMA) from AS (V), As (III), and MMAA. The cell

extracts or whole cells of Methanobacterium required adenosine triphosphate, hydrogen, and methyldonors with methylcobalamine (CH_3-B_{12}) (Ridley et al., 1977). This biomethylation and reduction process is shown in Figure 3-1. Moreover, three species of fungi, Candida humicola, Gliocladium and a Penicillum species, were found to form trimethylarsine from methylated arsenic substrate at neutral or acid pH. The Candida was able to methylate dimethylarsonic acid, monomethylarsonic acid, arsenate, and arsenite (Cox and Alexander, 1973). The trimethylarsine and dimethylarsine formed can be released into the air. Figure 3-2 shows the biological cycle for arsenic. In addition, Andreae (1979) proposed that biological demethylation is responsible for the regeneration of inorganic arsenic from methylated arsenicals.

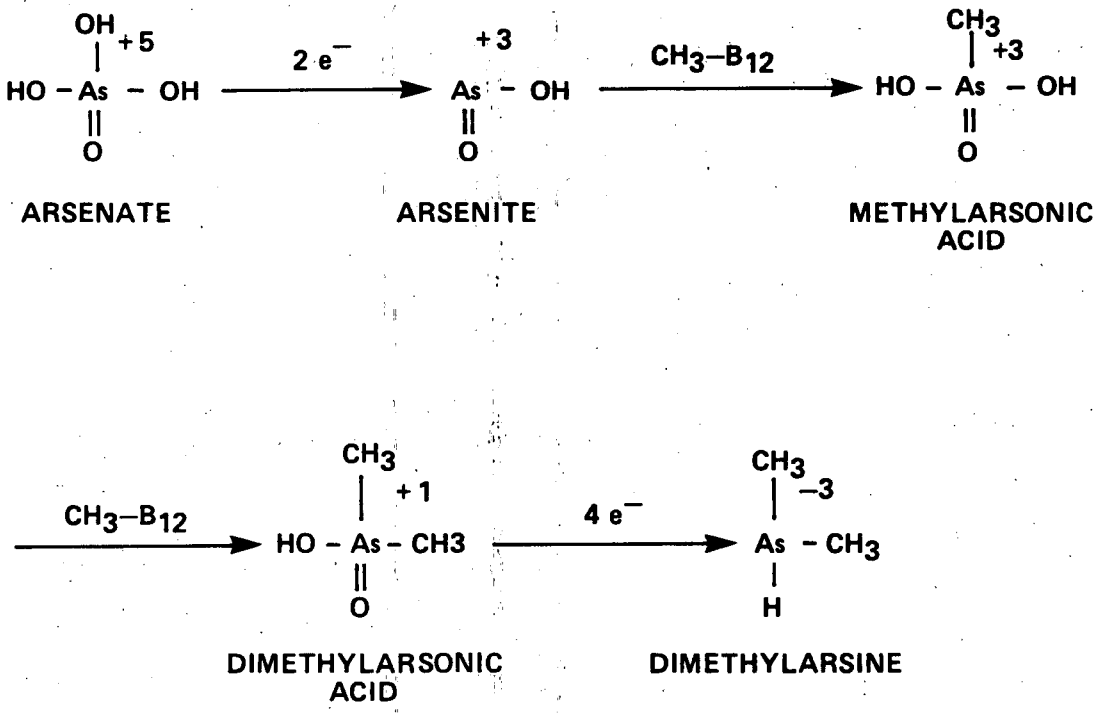
Precipitation/Dissolution

Arsenic can form insoluble precipitates with calcium, sulfur, iron, aluminum and barium compounds in natural waters. These reactions have been proposed as controls on aqueous phase arsenic concentrations (Ferguson and Gavis, 1972). Arsenic sulfide (As_2S_3) is suggested as being of particular importance under reducing conditions. However, the nucleation and growth rate of the arsenical precipitates are slow (Wagemann, 1978). Soluble arsenic species are more likely to be adsorbed on the surface of inorganic and organic substrates.

Adsorption/Desorption

Arsenic occurs in soil/sediment predominantly in an insoluble/adsorbed form. Arsenic has been shown to be adsorbed by a variety of sediment solid phase components including hydrous iron, aluminum and calcium oxides, clays and soil organic matter. In most geologic environments, evidence suggests the importance of soil iron oxides in adsorbing negatively charged anions preferentially such as arsenate. Woolson et al. (1971) found that most of the arsenic residue from soil with a history of As application was found as Fe-As. Other forms, Al-As and Ca-As, may predominate if the amount of "reactive" Al or Ca is high and reactive Fe is low. Arsenic adsorption appears to be better correlated to the clay content of the soil than to soil organic carbon content (Jacobs et al., 1970)(Wauchope, 1975). The reason for this relationship is that the hydrous iron and aluminum oxide contents of soils usually vary directly with the clay content of the soil.

However, for certain organic arsenate compounds, soil organic content may be a significant factor in overall mobility (Clement and Faust, 1981). Hydrous oxides also appear to be more effective adsorbers of arsenic on a surface area basis than are layer silicate components of clays. The adsorption process appears to be dependent upon both system pH and redox conditions. Maximum adsorption of arsenic as arsenate (+5)



SOURCE: McBride & Wolfe, 1971

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FIGURE 3–1

BACTERIAL REDUCTION OF ARSENATE

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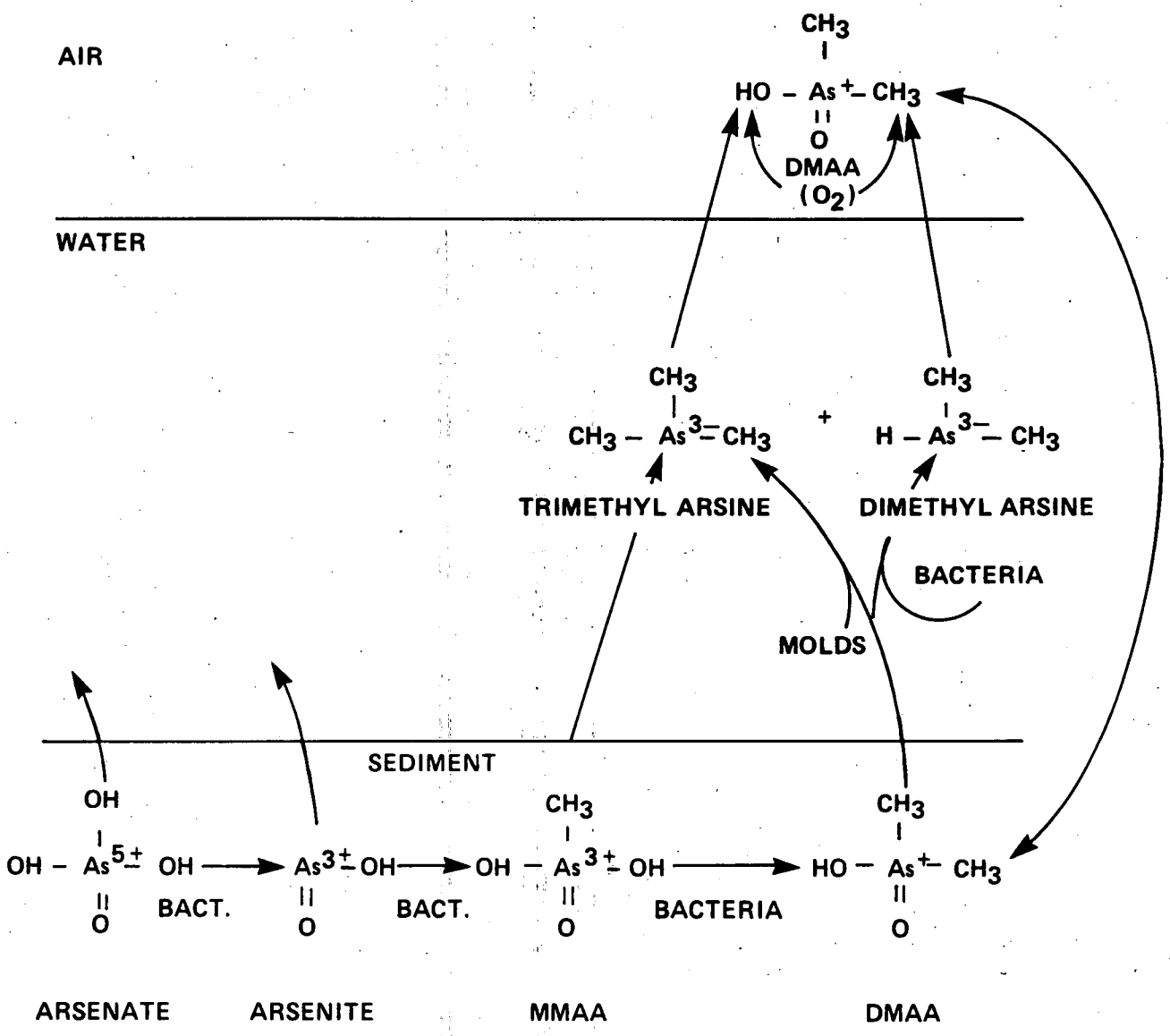

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VINELAND CHEMICAL COMPANY SITE
FIGURE 3–2 THE BIOLOGICAL CYCLE FOR ARSENIC
EBASCO SERVICES INCORPORATED

SOURCE: WOOD, 1974

occurs under acidic or neutral pH conditions, with decreasing adsorption and increasing pH over the pH 7-9 range. The maximum adsorption of arsenic as arsenite (+3) on hydrous oxides appears to occur in the pH 7-9 range (Rai and Zachara, 1984). Also, Gupta & Chen (1978) showed that the rate of adsorption decreases with increasing salinity and that pentavalent species have a greater adsorption affinity than do trivalent species. These data show that adsorption will be most important in aerobic, fresh water. As conditions become more reducing, alkaline, and/or saline, arsenic is less likely to be adsorbed and more likely to remain dissolved.

The relationships between the concentration of arsenic sorbed (adsorbed or desorbed) to solid phase soils or sediments and the aqueous phase arsenic concentration may be expressed in terms of a partition or distribution coefficient (K):

$$K = X/C \quad (1)$$

where:

X = amount of arsenic adsorbed in mg/kg, and
C = aqueous arsenic concentration in mg/l.

Factors which have been demonstrated to influence the magnitude of K for a constituent such as arsenic include:

- The experimental aqueous concentration range studied;
- The form and valence of arsenic;
- Solution pH; and
- Solid/solution ratios.

Experimentally measured arsenic partition coefficient values have been reported by a number of researchers for both sediments and soils of differing chemical composition.

Partition coefficient (K) values for arsenic adsorption (as arsenate) to three different U.S. soils have been estimated from the linear portions of Langmuir isotherms of data reported by Jacobs et al. (1979) and are found to be 8-28 l/kg. Estimated partition coefficients have been calculated from data reported for the adsorption of arsenic (as arsenate) to sediment (Wauchope and McDowell, 1984), and are estimated to be 19-102 l/kg.

Wauchope (1975) also observed that the partitioning of two organic arsenic herbicide compounds (methanearsonate - $H_2AsO_3CH_3$ and cacodylate - $HAsO_2(CH_3)_2$) was generally similar to that of the inorganic arsenic. For

equivalent initial solution arsenic concentration (2.5×10^{-3} M), maximum calculated K values (methanearsonate, K=75; cacodylate, K=46) are less than the maximum K values calculated for inorganic arsenate.

Available evidence indicates that the adsorption of arsenic to soils/sediment is not entirely reversible. Elkhatib et al. (1984) reported that isotherms of arsenite desorption from soils were strongly hysteritic. That is, for comparable experimental time frames, a fraction of previously adsorbed arsenic appeared to be irreversibly bound to the soil phase. In general, partition coefficients for desorption (Kd) were significantly greater than the analogous K values for adsorption. This suggests that the use of partition coefficients based on measured adsorption K values may not appropriately describe the current mobility of arsenic at sites of past contamination. Arsenic migration in most field systems is predominantly controlled by arsenic desorption from the solid phase. Therefore, it is the magnitude of Kd which is most appropriately applied to environmental fate studies.

Available information indicates that Kd for soil desorption is:

- o significantly greater than K for adsorption;
- o a function of soil chemical composition, including soil pH and iron oxide concentration; and
- o strongly affected by the soil redox levels.

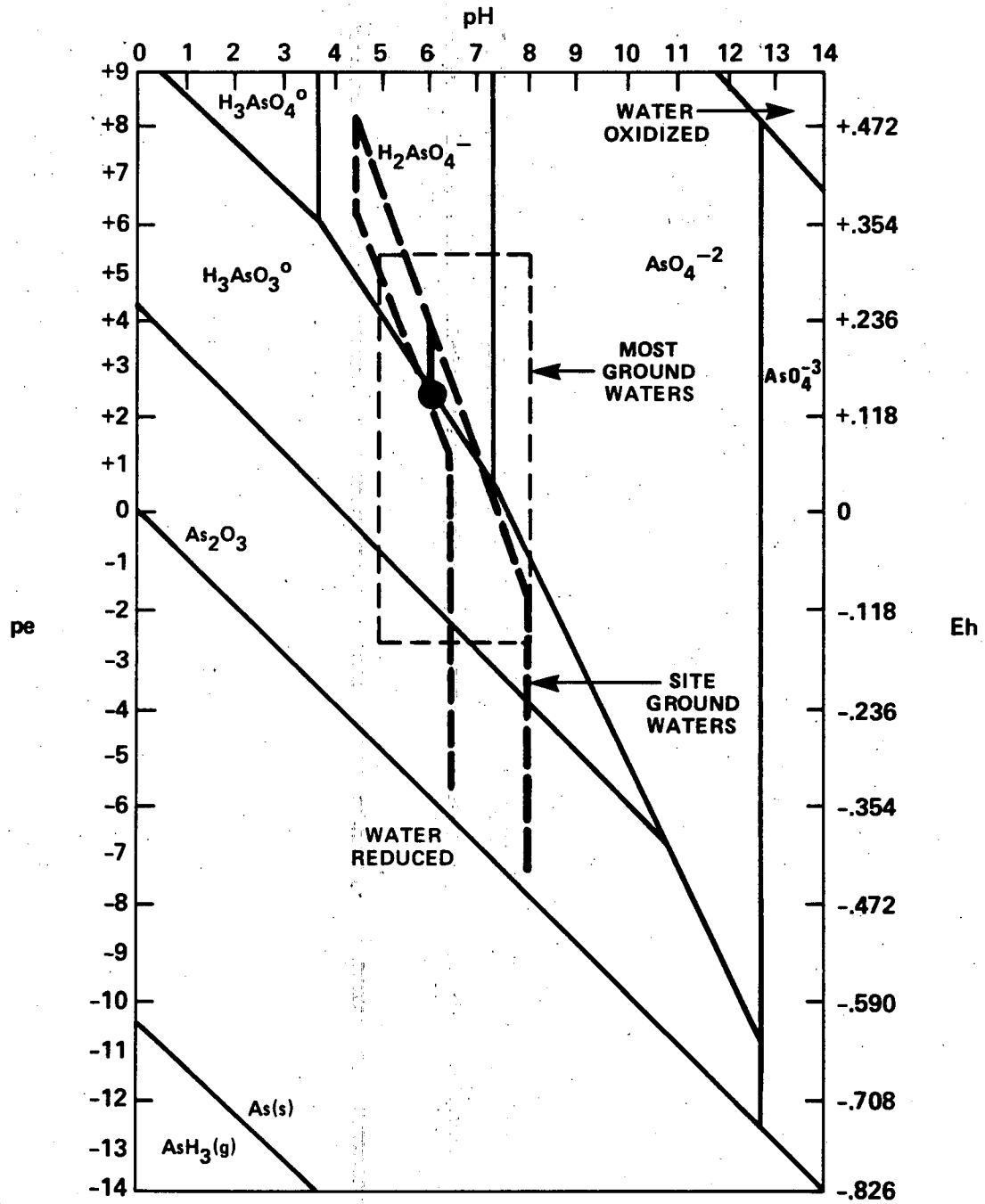
Partitioning to Sediments

The partitioning of arsenic between natural waters and sediments may be controlled by both precipitation and adsorption processes. At low aqueous phase arsenic concentrations, sediment-water partitioning may be predominantly controlled by adsorption/desorption processes rather than by direct precipitation (Clement and Faust, 1981).

In general, when runoff occurs, dissolved arsenic is accumulated in the sediment by three interrelated processes: sediment loading, solute adsorption onto the sediment, and "entrapment" in adsorbed solute as heavier sediment particles are left behind. The adsorption of arsenic to sediment is not an entirely reversible process and the sediment usually acts as a sink for arsenic. Faust et al., (1983) have shown that the arsenic concentrations in sediment at the bottom of Union Lake were as much as three orders of magnitude higher than in overlying waters.

Application to the Union Lake Site

The oxidation-reduction stability diagram for arsenic compounds is shown in Figure 3-3. Superimposed on the theoretical plot are site-specific conditions for Union Lake. The vertical dotted line represents a mean pH value of 6 for Union Lake. Assuming no or little change in this pH value, the redox conditions of Union Lake water would move up and down the



BASED ON CLEMENT & FAUST, 1973 AND FERGUSON & GAVIS, 1972.

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FIGURE 3–3

pH–pe OXIDATION-REDUCTION STABILITY DIAGRAM FOR ARSENIC COMPOUNDS

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vertical dotted line. The pe values in Figure 3-3 represent oxidizing conditions that are determined by the dissolved oxygen (D.O.) content of the water. In the hypolimnion, as the dissolved oxygen is removed from Union Lake water, the pe value would move down the vertical line until a value of +2 is reached when the arsenate (As +5) is reduced to arsenite (As^{+3}). Reducing conditions (- pe values), are encountered in the muds (bottom sediments) of Union Lake where the lower oxidation states of arsenic should predominate for interstitial waters.

Faust et al. (1983) reported total water column arsenic concentrations as high as 2.78 mg/l. Bottom sediment arsenic contents were reported to range up to 2290 mg/kg. Interstitial pore water arsenic concentrations were reported to range up to 12.5 mg/l.

In the 1986 sampling effort; arsenic concentrations up to 1270 mg/kg were found in the sediments. The sediment arsenic concentration was quite variable and exhibited a wide range over samples taken in close proximity to one another. The highest sediment arsenic concentrations were generally observed in the northern portion of the lake.

Ebasco, in its Phase I sampling program, has reported total sediment arsenic concentrations ranging from 12-107 mg/kg. Highest sediment arsenic concentrations were found in sediments in the lower lake area.

Aqueous phase total arsenic concentrations measured during Ebasco's Phase I program ranged up to 81 ug/l. The highest concentrations were observed in the mid and lower lake areas. Arsenic was primarily present in the dissolved form with maximum dissolved arsenic concentrations ranging up to 75 ug/l in the lower lake area. Particulate arsenic concentrations ranged up to 21 ug/l.

Somewhat lower total aqueous arsenic concentrations were observed during Ebasco's Phase II sampling program conducted during January, 1987. During this sampling event, the maximum total arsenic concentration was 187 ug/l; however, the mean total arsenic concentration was 34 ppb compared to a mean total arsenic concentration of 62 ug/l in Phase I. The Phase II mean dissolved arsenic concentration was 17.5 ug/l, compared to the mean dissolved arsenic concentration of 57.5 ug/l in Phase I. Relatively more arsenic was present in the particulate phase in Phase II than in Phase I, with mean concentrations of 16 ug/l compared to 9 ug/l, respectively.

For sediments of Union Lake, the arsenical species have been reported (Faust et al., 1983) to be of the following order with respect to decreasing concentration fractions:

$As^{+5} > As^{+3} >$ MMAA > DMAA.

In water, the order of predominance was found to be:

MMAA > As $^{+3}$ > As $^{+5}$ > DMAA.

Theoretically, it might be expected that the more reduced arsenite (+3) species might predominate in reduced sediments. However, it is possible that observed dominance of the arsenate (+5) species might reflect the analytical difficulties associated with the separation of the arsenic +3 and +5 species. Analytically, this separation is quite difficult to effect, and the results may be uncertain.

Alternately, it is also possible that arsenic was originally adsorbed to the sediment particulate matter under more oxidizing conditions (perhaps during transport to the lake) and subsequently deposited in the sediments. Any subsequent redox induced arsenic speciation changes are likely to be kinetically slow. Thus, the arsenic +5 species could exist for extended periods of time adsorbed or precipitated to the sediments.

Faust et al. (1983) evaluated partitioning in sediments and overlying waters in Union Lake. Desorption partition coefficient values were calculated based on the following equation:

$$Kd = \frac{\text{As concentration in sediment (mg/kg)}}{\text{As concentration in water (mg/l)}}$$

These authors reported desorption partition coefficient values ranging from 1050-4237 l/kg.

Sediment-water partition coefficient (K) values have also been calculated using the Phase I data for Union Lake. As indicated in Table 3-1, the calculated K values (l/kg) range from 179 l/kg to 7642 l/kg. These values were calculated using maximum observed sediment arsenic concentrations in different lake portions and the ranges of reported dissolved aqueous phase arsenic concentrations. The resulting calculated values are in general agreement with the range of values reported by Faust et al. (1983).

Overall, the sediments in Union Lake are probably acting as an arsenic reservoir and at least partially controlling arsenic concentrations in the overlying waters. Water column arsenic concentrations are, therefore, likely to remain relatively high for at least the near future. Maximum water column dissolved arsenic concentrations are likely to be observed in the lower (hypolimnion) waters during summer periods of low water column dissolved oxygen concentrations.

Water column total arsenic concentrations may reach maximum levels during time periods following hydrologic events which act to resuspend bottom sediments. Such events could include

TABLE 3-1

ESTIMATED UNION LAKE PARTITION COEFFICIENT DATA[1]

LOCATION	MAXIMUM SEDIMENT CONCENTRATION	DISSOLVED WATER CONCENTRATION RANGES	CALCULATED PARTITION COEFFICIENT (K) RANGE
PHASE I			
UPPER LAKE	65	44*-50*	1300-1427
MID-LAKE	12	48-67	179-250
LOWER LAKE	107	48-75	1426-2229
PHASE II			
UPPER LAKE	65[2]	21-41	1585-3095
MID-LAKE	12[2]	10-22	545-1200
LOWER LAKE	107[2]	14-16	6687-7642

(1) All sediment concentrations in mg/kg.
All water concentrations in ug/l.
K in l/kg.
* uncertain value

(2) Phase I sediment concentration data.

naturally occurring seasonal lake turn-over or storm events. They could also include artificially induced hydrologic events such as abrupt draining and filling the lake.

3.2.2 Waste Component Toxicity

Aquatic Biota

The mechanism of arsenic toxicity to aquatic organisms is not well understood; however, arsenic readily forms kinetically stable bonds with sulfur and carbon in organic compounds. Since arsenic (+3) reacts with sulfhydryl groups of proteins, enzyme inhibition by this mechanism may be the primary mode of arsenic toxicity. Arsenate (+5) does not react with sulfhydryl groups as readily but may uncouple oxidative phosphorylation (Anderson, et al., 1975).

In general, arsenic toxicity increased with longer duration of exposure for fish. Higher temperatures also appeared to increase arsenic toxicity (Sorenson, 1986), whereas water hardness had no significant effect. Effects of other parameters such as pH, suspended solids, and organic content in the water were not found in the literature.

Early life stages of freshwater aquatic organisms appear to be the most sensitive indicator of arsenic toxicity. The lowest value obtained for all of the trivalent inorganic arsenic data was for an early life stage exposure with the toad which resulted in a 7-day LC_{50} of 40 ug/l (Birge, 1979).

Acute Toxicity

The range of acute values for trivalent inorganic arsenic (sodium arsenite) in crustaceans varied from 812 to 5,278 ug/l. The range of LC_{50} values for the seven species of fish tested was from 13,340 to 41,760 ug/l (USEPA, 1980). The values reported for the few fish and invertebrate species exposed to sodium arsenate (+5) were comparable to those for exposure with these species to sodium arsenite. Thus, the two valence states appeared to be similarly toxic to aquatic organisms. For mammals, soluble As (+3) compounds are more toxic than pentavalent compounds. In addition, extremely high acute toxicity values were reported for species exposed to monosodium methanearsonate, indicating that organic arsenic may be much less toxic than both trivalent and pentavalent inorganic arsenic.

Chronic Toxicity

Only one chronic test has been found in the literature. In this life cycle test with Daphnia magna exposed to sodium arsenite a chronic value of 912 ug/l was observed (USEPA, 1980). USEPA has set a standard of 440 ug/l for the maximum recoverable trivalent inorganic arsenic concentration permitted in water for the protection of freshwater aquatic life (USEPA, 1980).

Human Effects

The major routes of arsenic exposure are inhalation or ingestion. Percutaneous absorption of arsenic can occur in man, but appears to be a relatively minor route of exposure except under certain occupational exposure conditions. Respiratory absorption of arsenic depends on chemical species of arsenic and the particulate size. Particles less than 1 um in diameter are deposited deeper in the respiratory tract and subsequently absorbed via the alveolar parenchyma. Larger particles tend to be deposited mainly in the upper portion of the respiratory tract, undergoing retrociliary movement, and ultimately are swallowed. Holland and coworkers (1954) observed that 75% to 85% of the deposited arsenic was absorbed from the lungs within four days. In man, gastrointestinal absorption of arsenic depends on the chemical form of the element and its physical characteristics. Soluble arsenicals are generally more extensively absorbed than the insoluble forms. It has been shown that greater than 95 percent of inorganic arsenic taken orally by man appears to be absorbed (Ray-Bettley and O'Shea, 1975). Once arsenic is absorbed into the blood stream, it is distributed to the heart, kidneys, liver, lungs and brain (Kadowski, 1980), but the highest arsenic levels are found in skin, hair, teeth, bone and nail. Thus, these are the arsenic storage organs.

Oral doses of about 70 mg - 180 mg of trivalent arsenic may be fatal to adults (Valle et al., 1960). Oral exposure of humans to arsenic produces a range of gastrointestinal disturbances, whereas hemolysis is the primary manifestation of arsine poisoning. The first symptoms of acute poisoning is often a feeling of throat constriction, followed by difficulty in swallowing, epigastric discomfort, and violent abdominal pain accompanied by vomiting and watery diarrhea. Intense thirst is usually present. Systemic collapse with severe hypotension probably reflects widespread damage to the muscular system. Death, which is generally preceded by restlessness, convulsions, or coma, may result from cardiac failure.

Chronic arsenic poisoning produces a range of symptoms including hyperpigmentation around the eyelids, temple, nipples, neck and groin; hyperkeratosis (precancerous skin lesions), "Blackfoot's disease" (peripheral vascular disease leading to gangrene of the extremities), hepatic and renal injury, peripheral and central neuropathy, and decreased hemoglobin production. Arsenic exposure has been shown to result in chromosome aberrations and sister chromatid exchange in humans (Burgdorf, 1977). There is clear evidence that chronic oral exposure to elevated levels of arsenic increases the risk of skin cancer. The most common lesions are squamous cell carcinomas which appear to develop from the hyperkeratinized lesions described earlier. Epidemiological studies of workers in smelters have indicated that inhalation exposure to arsenic may be associated with increased risk of lung cancer (USEPA, 1986).

3.2.3 Bioaccumulation in Aquatic Animals

Studies have shown that arsenic is not bioconcentrated to a high degree and that lower forms of aquatic life may accumulate more arsenic residues than fish. Arsenic accumulation in freshwater aquatic organisms does not appear to be greatly affected by the form of arsenic present, although the highest residues were seen in exposures to the trivalent inorganic form.

Isensee et al. (1973) investigated the bioaccumulation of two organic arsenicals, cacodylic acid and dimethylarsine for a total of 32 days in a model ecosystem that contains algae, snails, daphnia, and fish. The result was that fish exhibited the least accumulation, with a bioconcentration factor (BCF) of 21 for cacodylic acid and 34 for dimethylarsine. Snails accumulated the compounds to a greater extent, with bioconcentration factors which ranged from 110 to 446. Two planktonic components concentrated arsenic the most, with bioconcentration factors ranging from 736 to 2175. Thus it can be concluded that the arsenic compounds did not show a tendency to biomagnify (increase in concentration as trophic levels increase).

Available data have shown that arsenic bioaccumulation in fish varies widely and depends upon such aspects as water concentration, tissue measured, modes of uptake, health of the fish, position in the food chain, and types of experiment (i.e., lab versus field measurements) used to determine bioaccumulation.

BCF Estimation from Laboratory Studies

Sorensen (1976) reported the results of a 15-day exposure study of green sunfish to high levels of sodium arsenate in water (100, 500, 1000 mg/l). All levels were found to be toxic and the whole body BCFs ranged from 3.3 at 100 mg/l exposure to 0.58 at 1,000 mg/l exposure.

Spehar et al. (1980) reported the results of a 28-day flow through experiment with rainbow trout. Fish were exposed to 0.1 mg/l and 1.0 mg/l As concentrations, and the analytical detection limit for tissue As was 1 mg/kg and 6 ug/l for As in water. The BCFs derived from this study are for the whole body, and show that the lower the concentration the higher the BCF.

As Exposure (mg/l)	As in H_2O (mg/l)	As in Tissue mg/l	BCF*
Control	0.006	3	500
0.1	0.1	3	30
1.0	1.0	3	3

* BCF = $\frac{\text{As in tissue (mg/kg)}}{\text{As in } H_2O \text{ (mg/l)}}$

This high variability in BCF may be due in fact to measured levels in tissue being close to the detection limit for As.

Skinner et al. (1982) in a 128-day continuous flow through experiment measured whole body As uptake in bluegill and fathead minnow. The mean BCFs derived from this study ranged from 70-227 for fathead minnows and 45-70 for bluegill.

BCF Estimation from Field or Model Ecosystem Studies

In 1966, Gilderhus (1966) reported on the effects of the application of sodium arsenite to pools in which immature and adult bluegills were stocked. The pools were first covered with soil, then water, and stocked with typical bottom plants. The BCF values derived from the results after 16 weeks exposure ranged from 19 at 0.01 mg/l to 1.3 at 1.02 mg/l.

In a study of As in a contaminated aquatic ecosystem, Thompson et al. (1972) reported a BCF of 91. Skinner (1986) studied the effects of As on fish in effluent basins and measured water and fish muscle As levels. He found BCF levels to be as low as 1.3 for sunfish and as high as 60 for carp and catfish living in these basins.

The following table summarizes the results for BCF from the aforementioned studies:

Reference	Ref. No.	Study Type	BCF Range
Sorensen, 1976	37	lab	0.58 - 3.3*
Spehar et al., 1980	38	lab	3 - 500**
Skinner et al., 1982	39	lab	45 - 227***
Gilderhus, 1966	40	Model Ecosystem	1.3 - 45
Thompson et al., 1982	41	field	91
Skinner, 1986	42	field	1.3 - 60

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* Levels of exposure were toxic

** Measurements in fish tissue may not be different than the detection limit.

*** Whole body fish concentrations

Since the laboratory studies have significant experimental design limitations, bioaccumulation is probably best represented by field studies because uptake from all routes is assessed.

All of the field studies showed that the BCF for As is somewhere between 1 and 100. It is therefore assumed that 50 will be the best estimate of BCF with minimum and maximum values of 0.1 and 500, respectively.

During Ebasco's Phase II remedial investigation of the ViChem site, fish and water samples were collected from Union Lake. Five fish tissue samples were analyzed for total arsenic concentration. Table 3-2 shows the arsenic concentration in fish tissue, and the calculated bioconcentration factors.

3.2.4 Metabolism and Biotransformation

Arsenic metabolism has been investigated in animals and humans (Vahter, 1983)(Marafante and Vahter, 1987) and the following conclusions can be made:

- Dimethylarsenic acid (DMAA) is the major metabolite in most animals and humans. It is also the major metabolite that appears in urine.
- The major site of methylation is the liver.
- Monomethylarsenic acid (MMAA) is most often a secondary metabolite and its appearance in urine varies with the animal species.
- MMAA can be partially methylated to DMAA, but neither species is significantly demethylated to inorganic arsenic.
- Methylation is a detoxification step of inorganic arsenic, which increases the rate of arsenic excretion.
- Trivalent arsenic is the substrate for methylation, and arsenic (+5) must be reduced to arsenic (+3) before methylation can occur.
- Methylation is a dose-dependent process. The percentage of DMAA in urine decreases with increasing inorganic arsenic dose level, while the amount of retained arsenic increases.

Arsenic in marine organisms is primarily in the organic form. In a survey of arsenic in marine organisms, 0-7% of the total arsenic was found to be inorganic arsenic and most of the organic arsenic (84%) was water soluble and therefore more readily excreted.

In a study of smelter workers exposed to As_2O_3 and also individuals with typical dietary exposure to arsenic, Buchet et al. (1980) reported that urinary excretion of arsenic from these subjects was about 60% DMAA, 20% MMAA, and 20% inorganic

TABLE 3-2

BIOCONCENTRATION FACTORS OF ARSENIC
FOR FIVE FISH SPECIES IN UNION LAKE

Organism	As in H_2O (ug/l)	As in Fish Tissue (ug/kg)	BCF (l/kg)
Catfish species 1 (*Ictalurus sp.*)	16	220	13.8
Catfish species 2 (*Ictalurus sp.*)	16	110	6.9
Sucker (Family catostomidae)	16	20*	1.3
Sunfish (*Lepomis sp.*)	16	20	1.3
Pickerel (*Esox sp.*)	16	240 190 (d)	15

* Less than concentration listed
(d) Duplicate sample result for *Esox sp.*

arsenic. Braman and Foreback (1973) have also analyzed the urinary excretion of arsenic in four human volunteers. About two-thirds of the total urine arsenic concentrations were present as dimethylarsenic acid and 17% as pentavalent inorganic arsenic. Trivalent inorganic and methylarsenic acids were present at 8% each.

Arsenic can also be biotransformed by microorganisms in the environment (see Subsection 3.2.1). In marine organisms, arsenic is transformed to both lipid soluble and water soluble organic arsenic compounds. Algae in waters with low phosphate concentrations can metabolize arsenate to a membrane phospholipid, 0-phosphatidyltrimethylarsonium lactate (Benson and Summons, 1981) whereas in the flesh of fish, shellfish, and crustaceans, arsenobetaine is the principal organic arsenic compound (Cannon et al. 1983)(Tam et al. 1982).

4.0 SURFACE WATER AND SEDIMENT INVESTIGATION

4.1 APPROACH

The Union Lake field investigation was conducted in two phases. Phase I took place in June and July of 1986; Phase II took place in January of 1987.

The primary Phase I objective was to repeat the sampling at stations sampled by the NJDEP in 1979. Secondary objectives included: sampling at new locations to broaden the data base; developing a bathymetric contour map of Union Lake; estimating the spatial distribution of sediments within the lake; and testing equipment and field procedures to plan the Phase II effort.

The Phase II objective was to collect data specifically for the risk assessment (Section 7.0). The goal was to obtain supplemental data characterizing all possible exposure routes including ingesting fish from the lake.

4.1.1 Sample Locations

In Phase I of the field investigation, 31 surface water and 20 sediment samples were collected from 24 locations in Union Lake. Table 4-1 lists the sampling stations, the types of samples collected at each station, and the analyses performed on each sample. The Phase I sampling stations are shown in Figure 4-1.

Many of the Phase I sampling stations were chosen because these stations were previously sampled by the NJDEP in 1979. Some additional stations were established to broaden the data base. This included the traverse done at the southern end of the lake near the dam spillway, and at the northern end of the lake next to the submerged dam.

Surface water samples were obtained from the surface, mid-depth, and bottom (sediment-water interface) portions of the water column. Fifteen samples (including one duplicate sample) were collected from the surface of the water column. In addition, 14 bottom water samples (including one duplicate sample) and two mid-depth water samples were collected during Phase I. The sediment samples were obtained from the zero to one-foot intervals at each of the sediment sampling locations.

Seven field blanks were collected from the sampling devices used in Phase I. These devices included Wilco sediment corers, Kemmerer water samplers, and stainless steel buckets. Trip blanks were also shipped with samples scheduled for Hazardous Substance List (HSL) volatile organic analyses (VOA).

The Phase II surface water sampling effort consisted of the collection of 22 water samples from 11 sampling stations. Table 4-2 lists the sampling stations, the types of samples collected at each station, and the analyses performed on each sample. The sampling stations are shown in Figure 4-1.

TABLE 4-1

EBASCO PHASE I SAMPLING SUMMARY
(June - July, 1986)

SAMPLE STATION	DESCRIPTION	DATE SAMPLED	WATER ANALYSES					SEDIMENT ANALYSES					
			DISSOLVED ARSENIC & IRON	PARTICULATE ARSENIC & IRON	TOTAL HSL INORGANICS	HSL VOA	IN SITU[a] TESTS	TOC	TOTAL ARSENIC & IRON	TOTAL HSL INORGANICS	HSL VOA	SEDIMENT Eh	RESERVE SIZING
EL-1	Sediment, 0-1'	7/2/86	-	-	-	-	-	X	X	-	-	-	X
	Bottom Water		X	X	-	-	-	-	-	-	-	-	-
	Surface Water		-	-	-	-	X	-	-	-	-	-	-
EL-2	Sediment, 0-1'	7/2/86	-	-	-	-	-	X	X	-	-	-	X
	Bottom Water		X	X	-	-	X	-	-	-	-	-	-
	Surface Water		-	-	-	-	X	-	-	-	-	-	-
EL-3	Sediment, 0-1'	7/1/86	-	-	-	-	-	X	X	X	X	-	-
	Bottom Water		X	X	-	-	X	-	-	-	-	-	-
EL-4	Surface Water	6/29/86	X	X	X	X	X	-	-	-	-	-	-
	Mid-Water		X	X	-	-	X	-	-	-	-	-	-
	Bottom Water		X	X	-	-	X	-	-	-	-	-	-
EL-5	Sediment, 0-1'	6/29/86	-	-	-	-	-	X	X	X	X	-	-
	Surface Water	-	X	X	X	X	X	-	-	-	-	-	-
	Bottom Water	-	-	-	-	-	X	-	-	-	-	-	-
EL-6	Surface Water	6/29/86	X	X	X	X	X	-	-	-	-	-	-
EL-7	Surface Water	6/29/86	X	X	X	X	X	-	-	-	-	-	-
EL-8	Sediment, 0-1'	6/29/86	-	-	-	-	-	X	X	-	-	-	-
	Sediment, 0-1'		-	-	-	-	-	X	X	-	-	-	-
	Surface Water		X	X	X	X	X	-	-	-	-	-	-
	Surface Water		X	X	X	X	-	-	-	-	-	-	-
	Mid-Water		X	X	-	-	X	-	-	-	-	-	-
	Bottom Water		X	X	-	-	X	-	-	-	-	-	-
	Bottom Water		X	X	-	-	-	-	-	-	-	-	-
EL-9	Sediment, 0-1'	6/28/86	-	-	-	-	-	X	X	-	-	X	-
	Bottom Water		X	X	-	-	X	-	-	-	-	-	-
	Surface Water		-	-	-	-	X	-	-	-	-	-	-

TABLE 4-1 (Cont'd)

EBASCO PHASE I SAMPLING SUMMARY
(June - July, 1986)

SAMPLE STATION	DESCRIPTION	DATE SAMPLED	WATER ANALYSES					SEDIMENT ANALYSES					
			DISSOLVED ARSENIC & IRON	PARTICULATE ARSENIC & IRON	TOTAL HSL INORGANICS	HSL VOA	IN SITU[a] TESTS	TOC	TOTAL ARSENIC & IRON	TOTAL HSL INORGANICS	HSL VOA	SEDIMENT Eh	RESERVE SIZING
EL-10	Sediment, 0-1'	6/28/86	-	-	-	-	-	X	X	-	-	X	X
	Bottom Water		X	X	-	-	X	-	-	-	-	-	-
	Surface Water		-	-	-	-	X	-	-	-	-	-	-
EL-11	Sediment, 0-1'	6/28/86	-	-	-	-	-	X	X	-	-	X	-
	Bottom Water		X	X	-	-	X	-	-	-	-	-	-
	Surface Water		-	-	-	-	X	-	-	-	-	-	-
EL-12	Sediment, 0-1'	6/28/86	-	-	-	-	-	X	X	-	-	X	-
	Bottom Water		X	X	-	-	X	-	-	-	-	-	-
	Surface Water		-	-	-	-	X	-	-	-	-	-	-
EL-13	Sediment, 0-1'	7/2/86	-	-	-	-	-	X	X	-	-	-	X
	Bottom Water		X	X	-	-	X	-	-	-	-	-	-
	Surface Water		-	-	-	-	X	-	-	-	-	-	-
EL-14	Surface Water	7/2/86	X	X	-	-	X	-	-	-	-	-	-
	Bottom Water		X	X	-	-	X	-	-	-	-	-	-
EL-15	Surface Water	7/2/86	X	X	-	-	X	-	-	-	-	-	-
	Bottom Water		X	X	-	-	X	-	-	-	-	-	-
EL-16	Sediment, 0-1'	7/11/86	-	-	-	-	-	-	-	-	-	-	X
EL-17	Sediment, 0-1'	7/11/86	-	-	-	-	-	-	-	-	-	-	X
EL-18	Sediment, 0-1'	7/11/86	-	-	-	-	-	-	-	-	-	-	X
EL-19	Sediment, 0-1'	7/11/86	-	-	-	-	-	-	-	-	-	-	X
EL-20	Sediment, 0-1'	7/11/86	-	-	-	-	-	-	-	-	-	-	X
EL-21	Sediment, 0-1'	7/11/86	-	-	-	-	-	-	-	-	-	-	X
EL-22	Sediment, 0-1'	7/11/86	-	-	-	-	-	-	-	-	-	-	X
EL-23	Sediment, 0-1'	7/11/86	-	-	-	-	-	-	-	-	-	-	X
EL-24	Sediment, 0-1'	7/11/86	-	-	-	-	-	-	-	-	-	-	X

TABLE 4-1 (Cont'd)

EBASCO PHASE I SAMPLING SUMMARY
(June - July, 1986)

SAMPLE STATION	DESCRIPTION	DATE SAMPLED	WATER ANALYSES					SEDIMENT ANALYSES					
			DISSOLVED ARSENIC & IRON	PARTICULATE ARSENIC & IRON	TOTAL HSL INORGANICS	HSL VOA	IN SITU[a] TESTS	TOC	TOTAL ARSENIC & IRON	TOTAL HSL INORGANICS	HSL VOA	SEDIMENT Eh	RESERVE SIZING
	Blanks												
	Kemmerer-6/28 (Bottom Waters)	6/28/86	X	X	X	X	-	-	-	-	-	-	-
	Wilco Corer-6/28 (Sediments)	6/29/86	X	X	X	X	-	-	-	-	-	-	-
	Kemmerer-6/29 (Bottom Waters)	6/29/86	X	X	X	X	-	-	-	-	-	-	-
	Wilco Corer-6/29 (Sediments)	6/29/87	-	-	-	-	-	X	X	X	X	-	-
	Steel Bucket-6/29 (Surface Waters)	6/29/86	X	X	X	X	-	-	-	-	-	-	-
	Trip Blank-0630 (Samples from 6/28, 6/29, and 7/1)	6/30/86	X	X	X	X	-	-	-	-	-	-	-
	Kemmerer-7/2 (Bottom Waters)	7/2/86	X	X	X	X	-	-	-	-	-	-	-
	Wilco-7/2 (Sediments)	7/2/86	X	X	X	X	-	-	-	-	-	-	-
	Trip Blank-7/9 (Samples from 7/2)	7/9/86	X	X	X	X	-	-	-	-	-	-	-

a - In situ water quality = pH, Eh, temperature, specific conductance and salinity
X - Sample analyzed
HSL - Hazardous Substance List
VOA - Volatile Organic Compounds
TOC - Total Organic Carbon

N 206000
N 208000
N 210000
N 212000
N 214000
N 216000
N 218000
N 220000
E 1888000
E 1890000
E 1892000
N
REFERENCE STATION 4
REFERENCE STATION 1
REFERENCE STATION 2
PUBLIC BEACH
SUBMERGED DAM
EL-1
EL-2
EL-3
EL-4
EL-5
EL-6
EL-7
EL-8
EL-9
EL-10
EL-11
EL-12
EL-13
EL-14
EL-15
EL-16
EL-17
EL-18
EL-19
EL-20
EL-21
EL-22
EL-23
EL-24
EL-25
EL-26
EL-27
EL-28
EL-29
EL-30
ELB-1
ELB-2
ELB-3

LEGEND

- SEDIMENT AND WATER SAMPLING STATION
- WATER ONLY SAMPLING STATION
- SEDIMENT SIZING ONLY SAMPLING STATION
- BIOTA SAMPLING STATION

0 400 800 1600
SCALE IN FEET

VINELAND CHEMICAL COMPANY SITE - UNION LAKE

FIGURE 4-1

EBASCO SAMPLING STATIONS

EBASCO SERVICES INCORPORATED

TABLE 4-2

EBASCO PHASE II SAMPLING SUMMARY
(January, 1987)

SAMPLE STATION	DESCRIPTION	DATE SAMPLED	WATER ANALYSES				
			DISSOLVED ARSENIC	PARTICULATE ARSENIC	TOTAL HSL INORGANICS	HSL VOA	IN SITU[a] TESTS
	PHASE II						
EL-1	Mid-Water	1/8/87	X	-	X	-	X
EL-2	Surface Water	1/8/87	X	-	X	-	X
	Bottom Water		X	-	X	-	X
EL-3	Surface Water	1/7/87	X	-	X	-	X
	Bottom Water		X	-	X	-	X
EL-5	Surface Water	1/7/87	X	-	X	-	X
	Bottom Water		X	-	X	-	X
EL-8	Surface Water	1/7/87	X	-	X	-	X
	Bottom Water		X	-	X	-	X
EL-25	Surface Water	1/9/87	X	-	X	-	X
	Bottom Water		X	-	X	-	X
EL-26	Surface Water	1/9/87	X	-	X	-	X
	Surface Water		X	-	X	-	X
	Bottom Water		X	-	X	-	X
	Bottom Water		X	-	X	-	X
EL-27	Surface Water	1/9/87	X	-	X	-	X
	Bottom Water		X	-	X	-	X
EL-28	Surface Water	1/9/87	X	-	X	-	X
	Bottom Water		X	-	X	-	X
EL-29	Surface Water	1/9/87	X	-	X	-	X
	Bottom Water		X	-	X	-	X
EL-30	Mid-Water	1/9/87	X	-	X	-	X

a - In situ water quality tests include temperature, pH, Eh, dissolved oxygen, and specific conductance
X - Sample analyzed
HSL - Hazardous Substance List
VOA - Volatile Organic Analyses

6242b

Twenty water samples (including one duplicate sample) were collected at nine locations from both the upper portion of the water column and at the sediment/water interface. One additional water sample was collected at the mid-point of the water column at two locations (total of two samples).

A total of five field blanks were collected in Phase II. The field blanks were obtained from the Kemmerer samplers, Van Dorn samplers, and the stainless steel buckets used to take the water samples. Trip blanks were not prepared in Phase II, as none of the samples were scheduled for VOA analysis.

4.1.2 Sampling Methods

Surface Water

Water samples were taken at the surface and/or at depth within the water column during both phases of sampling. Samples were sent to a CLP laboratory for analysis. In situ water quality tests were also performed on selected samples (see Tables 4-1 and 4-2). The in situ tests were utilized solely during the field operations and are not addressed or analyzed in subsequent sections. The results are presented in Appendix D.

Surface water samples were taken with stainless steel buckets or beakers. Aliquots for the various analyses were poured out of these containers.

Water samples were taken at the bottom or at depth within the water column with Kemmerer or Van Dorn samplers. The depth of water at each station was measured, the opened sampler was lowered to the desired sampling depth, then the messenger was sent to close the sampler and obtain the sample from the desired interval.

All Phase I water samples were analyzed for total and dissolved arsenic and iron. Some Phase I water samples were also analyzed for total HSL inorganics and for HSL VOA.

The aliquots analyzed for total and dissolved arsenic were filtered through a filter with 0.45 um pore size in the field. The first 20 milliliters (ml) of filtrate that passed through each filter were discarded. The remainder of the filtrate was preserved with nitric acid to a pH of 2 or less. Both the filtrate and the filter from each sample were sent to a CLP laboratory for total arsenic and iron analyses.

The aliquots analyzed for total HSL inorganics and HSL VOA were not filtered. Both aliquots were poured directly from the sampling device into the appropriate sample containers. The total HSL inorganics aliquots were preserved with nitric acid to a pH of 2 or less, while the VOA aliquots were preserved with sodium thiosulfate.

All Phase II water samples were analyzed for total HSL inorganics and for dissolved arsenic. The aliquot for total inorganics was not filtered, while the aliquot for dissolved arsenic was filtered in the field by the same methods used in Phase I. Both aliquots were preserved with nitric acid to a pH of 2 or less.

In situ water quality tests were performed at most sample stations in both phases, as shown in Tables 4-1 and 4-2. In some cases, in situ tests were performed on water samples at the surface and at depth, while only the sample at depth was sent to CLP for analysis. The Phase I water quality tests were temperature, pH, Eh, dissolved oxygen, specific conductance, and salinity. The same tests were used in Phase II except for salinity, which was dropped because of the low values found in Phase I.

In Phase I, the in situ tests were performed with the probes suspended to the appropriate depth in the water column where possible. When tests were run on samples from greater than approximately ten feet deep, the samples were obtained with a Kemmerer and the tests were run on an aliquot from the sampler. In Phase II, all water quality tests were run on aliquots from the samplers because of the inclement weather conditions.

Sediment

Sediment samples were obtained only in Phase I. Sediment samples were not obtained in Phase II because of the extensive data base established by Ebasco's Phase I sampling and by NJDEP's August 1986 sediment sampling.

All of Ebasco's Phase I sediment samples were analyzed for total arsenic, total iron, and total organic carbon (TOC). Selected samples were also analyzed for total HSL inorganics and HSL VOA(+10), as shown in Table 4-1.

Sediment samples collected for chemical analyses were taken with a Wilco corer with a stainless steel liner. The depth of water at each station was measured, then the corer was lowered to the bottom suspended from metal rods. The corer was pushed into the sediment to obtain the maximum penetration. The sample was caught in the stainless steel liner.

The samples were removed from the liners, placed in stainless steel mixing bowls, then described visually. The cores were homogenized and samples were put into containers for TOC, total arsenic and iron, and total HSL inorganics analyses, as necessary. VOA samples were obtained from the cores before they were homogenized.

The design of Ebasco's Phase I program was to analyze samples from 0-1 feet and from 2-3 feet within the sediment column. This proved to be impractical because the sampler could not penetrate and hold samples at depth even in soft sediments. Therefore, Ebasco's Phase I results represent sediment from approximately 0-1 feet within the sediment column.

Some sediment samples were also taken to visually characterize the sediments at various locations, not for chemical analysis. These samples were taken with the same corer, but using a clear plastic instead of a stainless steel liner.

4.1.3 Quality Assurance and Quality Control

All equipment used to obtain surface water and sediment samples for chemical analysis was decontaminated prior to and subsequent to obtaining any given sample. Decontamination consisted of an Alconox wash, potable water rinse, ten percent nitric acid rinse, potable water rinse, acetone rinse, and final deionized water rinse. The equipment was allowed to air dry after the final deionized water rinse unless the equipment was needed immediately to collect another sample.

The schedule for equipment decontamination was as follows:

EQUIPMENT	WHEN TO DECONTAMINATE
o Kemmerer and Van Dorn samplers	After each use
o Stainless steel buckets and mixing bowls	After each use
o Wilco corer:	
- Stainless steel liner	After each use
- Cutting shoe	After each use
- Outer casing	Water rinse only
o Filter apparatus	After each use

Blanks

Field blanks were taken during Phase I and Phase II to detect cross-contamination from using the same sampling and filtering equipment repeatedly. Trip blanks were taken in Phase I to document cross-contamination occurring during shipping. Trip blanks were not taken during Phase II because samples for VOA analyses were not collected. Tables 4-1 and 4-2 list the blanks taken and the analyses performed.

Field blanks were taken after each day of sampling in Phase I. A blank was poured off of each type of equipment used on that day after the equipment had been decontaminated. The water used for the blank was distilled, deionized and organic free (laboratory analyzed). The handling and preservation of the field blanks were the same as for the samples which were collected, including filtration.

Trip blanks were sent with each Phase I sample shipment. The water used was the same type as the field blanks. The trip blanks were poured directly into the sample containers. Metals trip blanks were preserved with nitric acid, while VOA trip blanks were preserved with sodium thiosulfate.

The field blanks in Phase II were taken from each type of equipment at the end of the sampling exercise. The blanks were composed of distilled deionized, organic free water poured over the decontaminated sampling equipment.

4.1.4 Bathymetric Mapping of Union Lake

A bathymetric map of Union Lake was made from data collected in Phase I. The map was presented as Figure 2-1 in Subsection 2.1. The methods to obtain the data are described in this section.

A Motorola Mini-Ranger III Positioning system was used to locate points where the lake depth was measured and a Raytheon Model DE-719B recording Fathometer Depth Recorder was used to record the lake depth. Additional equipment included a steel tape to ground the fathometer during operation.

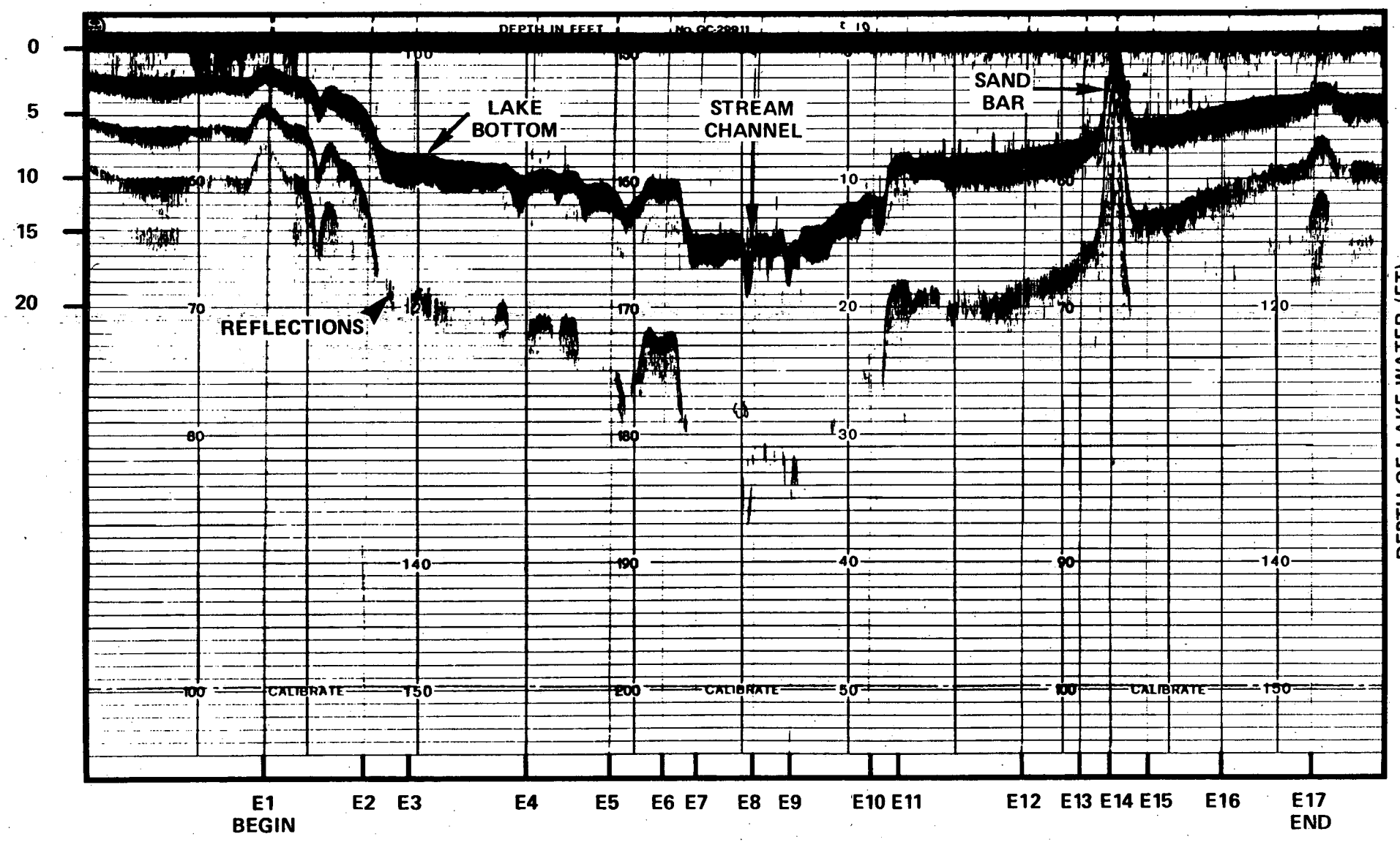
The Mini-Ranger III Positioning system operates on the principle of pulse-radar. A transmitter/receiver on the boat interrogates transponders placed at reference points on shore. The elapsed time between transmission and reception gives the distance between the boat and the reference stations. The simultaneously recorded distances between the transmitter/receiver on the boat and two reference points on shore can be used to triangulate the location of the boat.

The Raytheon fathometer is also a transmitter/receiver that computes water depth by the time interval between a signal being sent to and received from the bottom. The machine provides a continuous and permanent recording of water depth. The machine reportedly can indicate soft or hard bottom conditions by the shape of the trace it makes. However, field personnel discovered that there was little correlation between bottom conditions and the printout in the Union Lake survey.

The procedure for mapping the lake bathymetry was to cross the lake from side to side along 16 arbitrarily drawn traverses. At predetermined intervals along each traverse, the distances from two reference stations on the Mini-Ranger were frozen and recorded. Simultaneously, the permanent record from the fathometer was marked to indicate the point corresponding to the Mini-Ranger coordinates. In all, over 200 points were located with the Mini-Ranger where the depth was measured with the fathometer. Approximately 180 of these points were along traverses, while the remainder were random points such as chemical sampling stations. An example of the fathometer print-out from one of the traverses is presented in Figure 4-2.

FIGURE 4-2

FATHOMETER TRACE FROM TRAVERSE E OF UNION LAKE BATHYMETRIC SURVEY



To construct the bathymetric map, the Mini-Ranger coordinates of each measuring point were tabulated and the reference stations were placed on a large-scale map of the lake. The distances between each measuring point and the two reference transponders were drawn on the map in arcs. The intersection of the two arcs marked the location of the measuring point in the lake.

The fathometer record was then used to establish the depth of water at each measuring point. Because the fathometer made a continuous permanent record, bottom features between known points on a traverse could be located. In this way, the old stream channel was found as shown in Figure 4-2.

4.2 FIELD INVESTIGATION RESULTS

This section summarizes the sediment and surface water data collected by Ebasco in Union Lake, as well as the results of three prior sampling programs conducted by or for NJDEP in Union Lake. The NJDEP data were included to enable the Risk Assessment and Feasibility Study to be based on all existing data available and thus be as comprehensive as possible.

The NJDEP data consist of samples taken from the following matrices: 1) Union Lake sediment and water sampled quarterly in 1982-83; 2) lake sediment collected in April, 1986; and 3) lake sediment sampled in August, 1986.

All data (Ebasco's and NJDEP's) have been reviewed and validated. Ebasco's Phase I and Phase II sampling events were rejected and/or qualified by the USEPA Environmental Services Division (ESD). Rejection was principally for: 1) poor matrix spike recoveries; 2) out of specification correlation coefficients when using standard addition techniques; 3) contaminated laboratory preparation blanks; and 4) slight contamination of field blanks. In addition, some concentrations were estimated due to poor precision among laboratory duplicates.

While rejection for out of specification correlation coefficients is justifiable, rejections for violating other criteria are less severe when concentrations of the analytes of interest are high (i.e., greater than 1 to 2 orders of magnitude above detection limits). Considering the high arsenic levels found in the lake samples (up to 107 mg/l), the high variability seen within the duplicates is not anomalous or unexpected. In addition, the high concentration levels present in the Union Lake sediment samples in relation to the levels found within the blanks (generally several orders of magnitude difference), negate the severity of violating these criteria set forth in EPA's data validation standard operating procedures.

Therefore, rather than lose some pertinent site data, these data have been appropriately footnoted and included within the report. Although rejected data were included in the report, no conclusions were based upon rejected data.

In the River Areas RI Report, the results of sediment and water samples taken in the Blackwater Branch and the upper Maurice River upstream from the ViChem Plant site are presented. These samples establish the background level of arsenic in the area. In both the Blackwater Branch and the Maurice River, the upstream water arsenic concentration was less than 10 ug/l, while the upstream sediment arsenic concentration was less than 2 mg/kg. Both of these values represent the detection limit for arsenic. In the discussion that follows, the arsenic concentration levels within the lake should be viewed in terms of these background levels.

4.2.1 NJDEP Results

The NJDEP samples collected in 1982-1983 were analyzed for total arsenic. The data set consisted of five sediment and five water samples each taken quarterly in September, December, March, June and September (1982-1983). Sediment arsenic concentrations ranged from 0.08 mg/kg to 23.2 mg/kg. Arsenic levels within the sediments were generally greatest within lake sediments near the submerged dam in the northern sector of Union Lake, and adjacent to the main dam at the southern end of the lake. Water arsenic levels ranged from 27 ug/l to 267 ug/l. Water arsenic values (unfiltered) were variable within each sampling quarter (probably due to suspended lake sediment within the sample) and between sampling periods. The raw data indicated a seasonal pattern of arsenic within the water column, with the lowest values typically occurring in winter and the highest levels in summer and early fall. Seasonal patterns among arsenical species within Union Lake consistent with the NJDEP results were observed (Winka, 1985).

Eighteen Union Lake sediment samples obtained in April, 1986 by NJDEP adjacent to the spillway corroborated earlier findings of high arsenic levels in lake sediments. Sixteen grab samples and two core samples analyzed for total arsenic showed that arsenic contamination was a surficial phenomenon, with surface sediment arsenic concentrations ranging from 16-506 mg/kg.

A large-scale sampling of Union Lake sediments was performed by NJDEP in August 1986. In this study, 193 surface sediment samples were taken. These samples were analyzed for total arsenic and percent sand. Twenty-three sediment cores were also obtained, with 57 samples taken from these cores. Thirty-six samples were obtained from 12 cores at three intervals (surface, 0-1 foot interval, and 0-2 foot interval). Twenty samples were collected from ten cores at the surface and at the 0-1 foot interval. One sample was collected from the 0-1 foot interval from one core. Figure 4-3 shows the location of each of these sediment sampling points.

Sediment arsenic concentrations and percent sand values determined from the surface sediment samples in the 1986 NJDEP study are presented in Figures 4-4 and 4-5, respectively. The results of the arsenic analyses from the core samples are shown in Table 4-3 and are summarized as follows:

N 206000 N 208000 N 210000 N 212000 N 214000 N 216000 N 218000 N 220000

E 1886000

E 1888000

E 1890000

E 1892000

PUBLIC BEACH

LEGEND

- ● SURFACE SEDIMENT
- ▲ SEDIMENT CORE

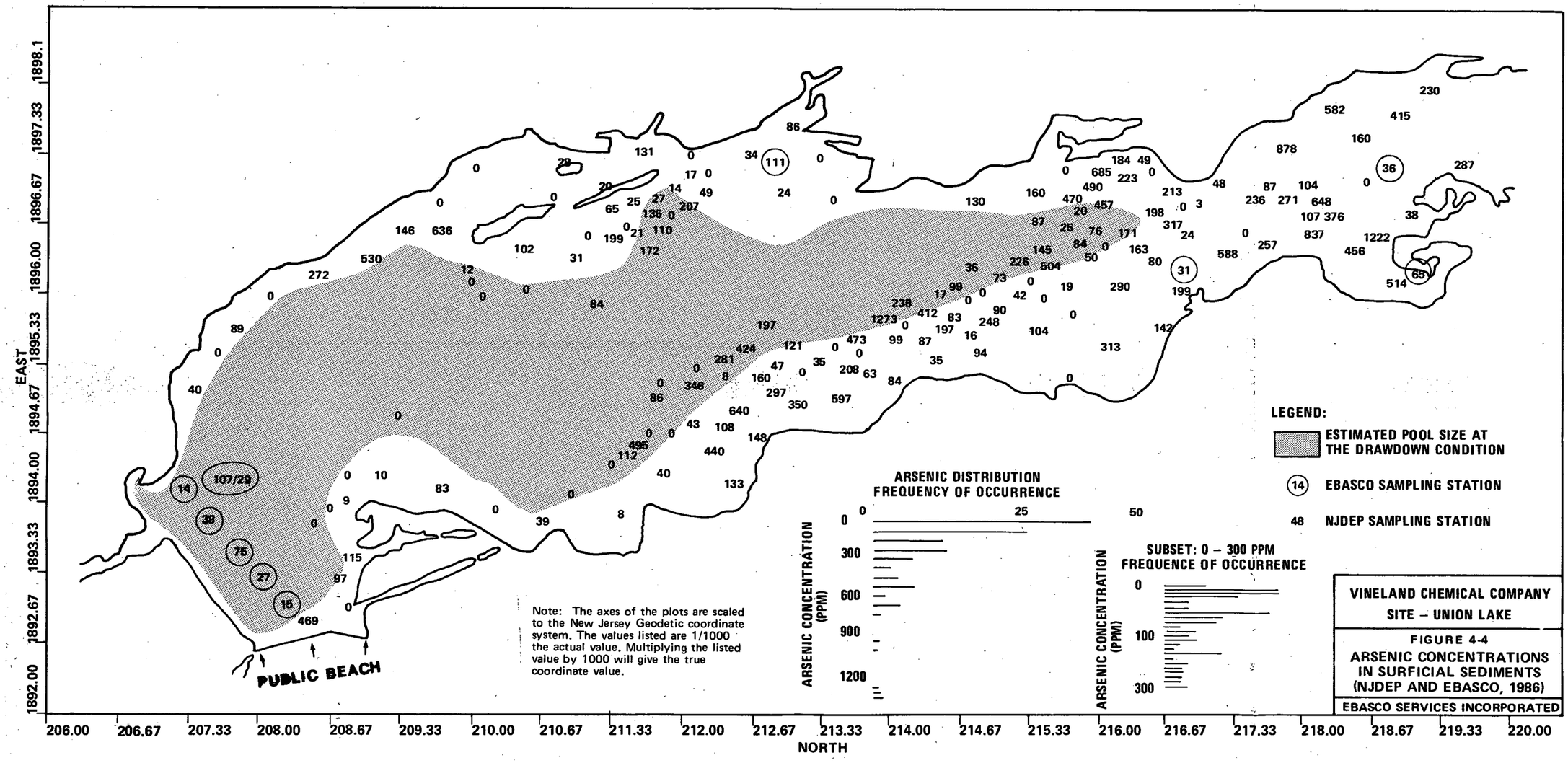
0 400 800 1600
SCALE IN FEET

VINELAND CHEMICAL COMPANY SITE - UNION LAKE

FIGURE 4-3

NJDEP 1986 SEDIMENT SAMPLING STATIONS

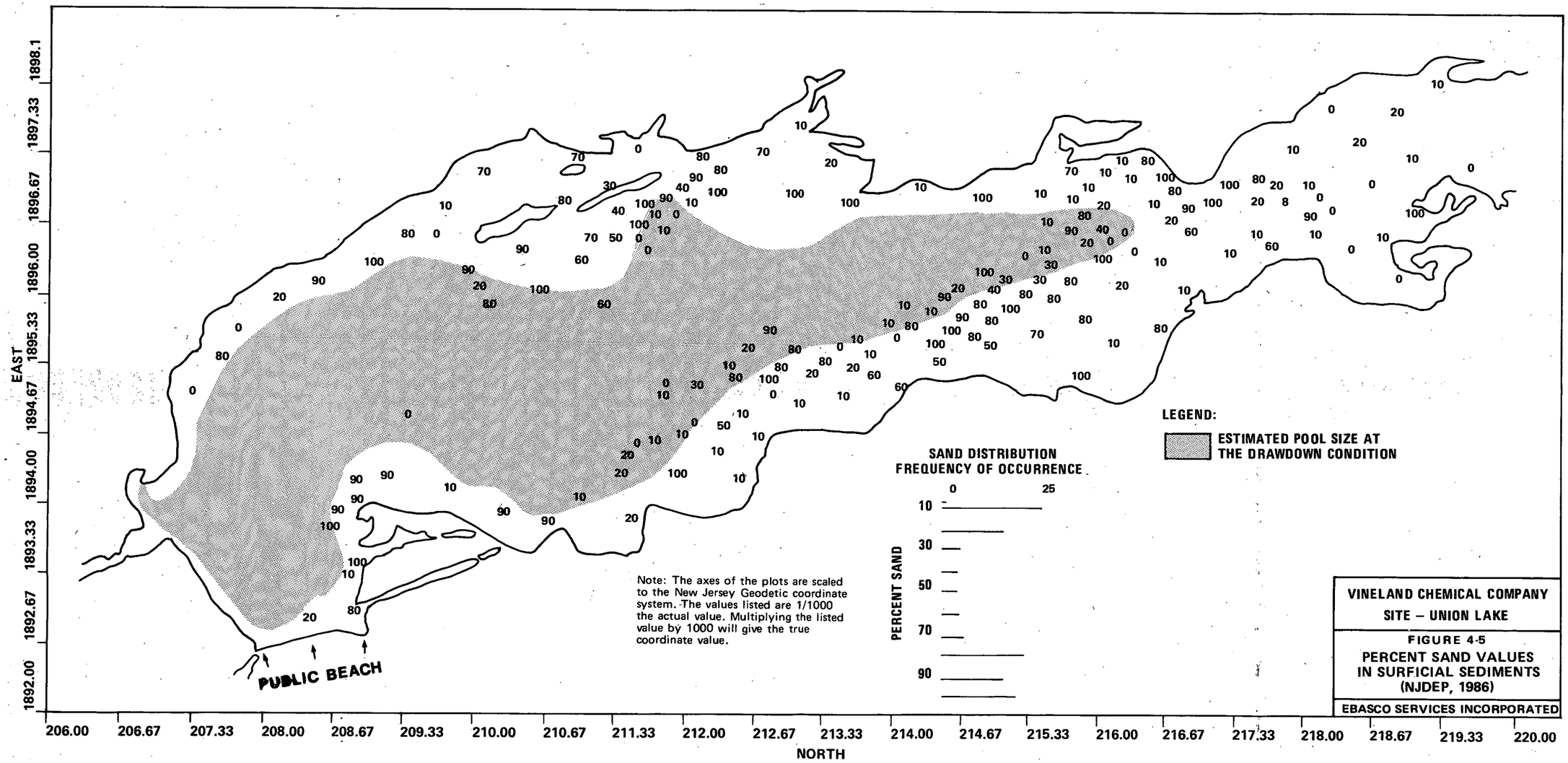
EBASCO SERVICES INCORPORATED



VINELAND CHEMICAL COMPANY
SITE – UNION LAKE

FIGURE 4-4
ARSENIC CONCENTRATIONS IN SURFICIAL SEDIMENTS (NJDEP AND EBASCO, 1986)

EBASCO SERVICES INCORPORATED


EAST
1898.1
1897.33
1896.67
1896.00
1895.33
1894.67
1894.00
1893.33
1892.67
1892.00
206.00
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216.00
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218.00
218.67
219.33
220.00
NORTH
PUBLIC BEACH
LEGEND:
ESTIMATED POOL SIZE AT THE DRAWDOWN CONDITION
SAND DISTRIBUTION
FREQUENCY OF OCCURRENCE
0
25
PERCENT SAND
10
30
50
70
90
Note: The axes of the plots are scaled to the New Jersey Geodetic coordinate system. The values listed are 1/1000 the actual value. Multiplying the listed value by 1000 will give the true coordinate value.
VINELAND CHEMICAL COMPANY
SITE – UNION LAKE
FIGURE 4-5
PERCENT SAND VALUES IN SURFICIAL SEDIMENTS (NJDEP, 1986)
EBASCO SERVICES INCORPORATED

TABLE 4-3

NJDEP ANALYTICAL RESULTS OF SEDIMENT CORE SAMPLES
COLLECTED FROM UNION LAKE, AUGUST, 1986[a]

Core Sample Number	ARSENIC CONCENTRATION (mg/kg)			PERCENT SOLIDS (%)		
	Surface	0-1 Foot	1-2 Foot	Surface	0-1 Foot	1-2 Foot
C1A	636	ND		9.4	19.7	
C5	33[b]	2	2	24.4	89.5	93
C6	ND	133		15.9	11.7	
C7	16.8	2		73.8	89	
C9	ND	130		20.2	9.5	
C10	95	ND	ND	16.7	79.7	79.5
C11	ND	ND	2	89	94.4	90.9
C12	3	3		77.5	74.2	
C13		2			81	
C14	271	31	3	18	36.2	73.3
C15	376	ND	3	13.9	42.1	78.4
C16	284	ND	2	12.4	65.8	91.8
C17	226	3	3	15.6	81.6	93.0
C18	ND	ND		78	16.9	
C22	99	ND	9	14.6	17.1	21.5
C23	ND	12		11.2	16.3	
C25	297	10		19.7	19.7	
C26	ND	13		77.9	92.2	
C28	43	9	3	20.2	23.1	79.1
C29	495	8	7	16.2	24.2	28.0
C30A	89	33		15.9	23.6	
C31	ND	174	ND	28.1	31.1	50.6
C32	ND	ND	ND	13.3	39.6	77.7

---

a Values are from core samples only. Surficial sediment arsenic results are shown in Figure 4-4.

b Value is the average of the duplicate sample results (ND and 65 mg/kg) Blanks indicate sample was not analyzed.

ND - Arsenic was not detected in the sample.

Interval	Number of Samples	Concentration Range	Median Value
Surface	22	ND-636 mg/kg	33 mg/kg
0-1 Foot	23	ND-174 mg/kg	3 mg/kg
1-2 Foot	12	ND-9 mg/kg	3 mg/kg

It should be noted that the sediment sizing data from this sampling event may be suspect. The percent silt and clay content of the samples was not determined along with the percent sand content. Therefore there is no means to check on the total sample recovery from the sizing procedure, which makes the accuracy of the percent sand determination suspect.

4.2.2 Ebasco Phase I Results

Water Results

As shown in Table 4-1, all of Ebasco's Phase I water samples were analyzed for dissolved and particulate arsenic and iron. An aliquot of each sample was filtered in the field and both the filter particulate and the filtrate were analyzed for arsenic and iron. Total arsenic and iron concentrations were obtained by summing the filtrate and the filter particulate analyses.

Six surface water samples were also submitted for HSL inorganic analyses. These samples were not filtered in the field. The results therefore represent the sum of the dissolved and particulate fractions in the water. These six water samples were also analyzed for HSL VOA.

The Phase I surface water results are presented in Table 4-4. Twelve bottom waters (plus one duplicate), seven surface waters (plus one duplicate) and two mid-depth water samples were submitted for analysis (see Figure 4-1 for sampling locations).

Dissolved arsenic concentrations ranged between 48 ug/l to 75 ug/l with a median value of 58 ug/l. This concentration range is consistent with summer arsenic values measured by NJDEP in 1982-1983. No large differences existed between dissolved arsenic concentrations measured in surface, mid-depth, or bottom water samples. Particulate arsenic concentrations measured on the filter paper from the filter apparatus ranged from 3.8-21 ug/kg. The highest values were typically seen in the bottom water samples.

Dissolved iron concentrations ranged from 605-871 ug/l. Particulate iron concentrations ranged from 83-460 ug/kg. The higher values were typically seen in the bottom water samples. The results, as discussed in Section 4.2, were rejected by USEPA ESD.

The total arsenic and iron results were obtained by summing the particulate and dissolved fractions. Most of the arsenic and iron was found in the dissolved phases. Total arsenic concentrations ranged between 54-81 ug/l. The higher levels

TABLE 4-4

EBASCO PHASE I SURFACE WATER ANALYTICAL RESULTS (ug/l)
(June - July, 1986)

SAMPLE STATION	DESCRIPTION	PARTICULATE		DISSOLVED		TOTAL		TOTAL HSL INORGANICS	HSL VOLATILE ORGANICS
		As	Fe	As	Fe	As	Fe		
EL-1	Bottom Water	21.0	460	44(R)	680 (R)	65(RT)	1140(RT)	NA	NA
EL-2	Bottom Water	16.0	343(R)	50(R)	730 (R)	66(RT)	1073(RT)	NA	NA
EL-3	Bottom Water	8.5	194	67	871 (R)	75.5	1065(RT)	NA	NA
EL-4	Surface Water	5.9	116	58	702 (R)	63.9	818(RT)	As 70 Ba 51 Ca 1680 K 2190 Mg 2530 Mn 41	ND
EL-4	Mid-Water	7.0	140	52	683(R)	59.0	823(RT)	NA	NA
EL-4	Bottom Water	7.6	185	50	745(R)	57.6	930(RT)	NA	NA
EL-5	Surface Water	8.8	369	53	803(R)	61.8	1172(RT)	As 68 Ba 54 Ca 1820 K 2690 Mg 2370 Mn 41 Cd 5.8 Hg 0.3	ND
EL-6	Surface Water	9.9	197	65	605(R)	74.9	802(RT)	As 66 Ba 50 Ca 1600 K 23600 Mg 2530 Mn 43	ND
EL-7	Surface Water	3.8	83	53	675(R)	56.8	758(RT)	As 72 Ba 46 Ca 1490 K 1980 Mg 2320 Mn 38	ND
EL-8	Surface Water	5.7	109	48	680(R)	53.7	789(RT)	As 69 Ba 49 Ca 1480	ND

TABLE 4-4 (Cont'd)

EBASCO PHASE I SURFACE WATER ANALYTICAL RESULTS (ug/l)
(June - July, 1986)

SAMPLE STATION	DESCRIPTION	PARTICULATE As	PARTICULATE Fe	DISSOLVED As	DISSOLVED Fe	TOTAL As	TOTAL Fe	TOTAL HSL INORGANICS	HSL VOLATILE ORGANICS
								K 2270 Mg 2600 Mn 37	
EL-8	Surface Water (Duplicate)	5.0	96	60	403(R)	65.0	499(RT)	As 68 BA 51 Ca 1600 K 2280 Mg 2630 Mn 40	ND
EL-8	Mid-Water	5.1	128	55	623(R)	60.1	751(RT)	NA	NA
El-8	Bottom Water	6.3	130	68	715(R)	74.3	845(RT)	NA	NA
EL-8	Bottom Water (Duplicate)	6.7	140	67	710(R)	73.9	850(RT)	NA	NA
EL-9	Bottom Water	5.3	116	69	698(R)	74.3	814(RT)	NA	NA
EL-10	Bottom Water	5.9	118	66	698(R)	71.9	816(RT)	NA	NA
EL-11	Bottom Water	6.4	166	75	722(R)	81.4	888(RT)	NA	NA
EL-12	Bottom Water	10.2	222	64	779(R)	74.2	1001(RT)	NA	NA
EL-13	Bottom Water	10.2	196(R)	58(R)	703(R)	68.2(RT)	899(RT)	NA	NA
EL-14	Surface Water	19.2	409	59(R)	718(R)	78.2(RT)	1127(RT)	NA	NA
EL-14	Bottom Water	13.1	278(R)	55(R)	666(R)	68.1(RT)	944(RT)	NA	NA
EL-15	Surface Water	4.4	106(R)	62(R)	756(R)	66.4(RT)	862(RT)	NA	NA
EL-15	Bottom Water	7.5	138(R)	55(R)	820(R)	62.0(RT)	958(RT)	NA	NA

NA - Not Applicable or Available
ND - Not Detected
R - Data Rejected
RT - Rejected Total (Value calculated with either one or both values [dissolved and particulate] being rejected)
HSL - Hazardous Substance List

were seen in the bottom samples and included the higher particulate results. The total iron concentrations ranged between 751 ug/l and 1172 ug/l.

Six surface waters were analyzed for HSL inorganic and HSL volatile organic compounds. As Table 4-4 shows, no organic volatile compounds were detected in any of the Union Lake samples. Among the HSL inorganic elements, arsenic (66 - 72 ug/l), barium (49 - 54 ug/l), calcium (1480 - 1820 ug/l), potassium (1980 - 23600 ug/l), magnesium (2320 - 2630 ug/l) and manganese (37 - 43 ppb) were the principal components found. Cadmium (not detected (ND) - 5.8 ug/l) and mercury (ND - 0.3 ug/l) were also detected, but these two compounds were only present in one of the water samples. As the duplicate sample results in Table 4-4 indicate, precision was quite good within the sampling program for both top and bottom water samples regardless of the analysis performed (i.e., dissolved versus total HSL inorganics, etc.)

Sediment Results

Sediment results are presented in Table 4-5. Ten sediment samples were submitted for total arsenic, iron and total organic carbon analyses (see Figure 4-1 for sampling locations). Two of these samples were also submitted for HSL inorganic and HSL volatile organic compounds analyses.

The sediment samples consisted primarily of soft black organic material. Some sediments were coarse sands. As discussed previously, no correlation was found between areas of the lake and sediment type. Samples taken in close proximity tended to vary widely in composition.

As Table 4-5 shows, total arsenic ranged from ND to 111 ppm, total iron from 268 ppb to 4140 ppm and total organic carbon ranged from 9% to 17.3%. No HSL volatile organic compounds were detected.

Among the HSL inorganic compounds, arsenic (31 - 111 mg/kg), barium (21 - 166 mg/kg), calcium (684 - 2480 mg/kg), copper (16 - 45 mg/kg), iron (1070 - 7120 mg/kg), manganese (31 - 63 mg/kg) and nickel (13 - 26 mg/kg) were the principal components found in the lake sediment. Zinc (90 mg/kg), beryllium (2.9 mg/kg), tin (35 mg/kg), aluminum (211 mg/kg), lead (50 mg/kg) and vanadium (19 mg/kg) were also present in one out of the two samples submitted for total HSL inorganic analysis. As the results indicate, the metallic components of the lake sediments and their concentrations are quite variable and show great spatial heterogeneity. These results are consistent with earlier results obtained by NJDEP.

One duplicate sample analysis was performed on a sediment sample. The results of this duplicate indicate that the reproducibility between sediment samples was poor. However, considering that this sample is a 0-1 foot composite and that arsenic contamination is principally a surficial phenomenon in the lake sediments, this is not unexpected.

TABLE 4-5

EBASCO PHASE I SEDIMENT ANALYTICAL RESULTS (mg/kg)
(June - July, 1986)

SAMPLE STATION	DESCRIPTION	TOTAL As	TOTAL Fe	TOTAL ORGANIC CARBON (%)	TOTAL HSL INORGANICS	HSL VOLATILE ORGANICS
EL-1	Sediment, 0-1'	65.3	638	17.3	NA	NA
EL-2	Sediment, 0-1'	36	1190	16.7	NA	NA
EL-3	Sediment, 0-1'	ND	268	NA	As 31 Ba 21 Ca 684 Cu 16 Fe 1070 Mn 31 Ni 13 Sn 35 Al 211	ND
EL-5	Sediment, 0 1'	12	820	NA	As 111 Ba 166 Ca 2480 Cu 45 Fe 7120 Mn 63 Ni 26 Pb 50 V 19 Zn 90 Be 2.9	ND
EL-8	Sediment, 0-1'	29	1490	NA	NA	NA
	Sediment, 0-1' (Duplicate)	107	3010	NA	NA	NA
EL-9	Sediment, 0-1'	15	2230	NA	NA	NA
EL-10	Sediment, 0-1'	27	1900	NA	NA	NA
EL-11	Sediment, 0-1'	75	2179	NA	NA	NA
EL-12	Sediment, 0-1'	38	2010	NA	NA	NA
EL-13	Sediment, 0-1'	14	4140	9.0	NA	NA

NA - Not Analyzed
ND - Not Detected
HSL - Hazardous Substance List

6242b

TABLE 4-6

EBASCO PHASE II SURFACE WATER
ANALYTICAL RESULTS (ug/l)

SAMPLE STATION	SAMPLE DEPTH	DISSOLVED ARSENIC	Al	Sb	As	Ba	Ca	Cd	Cr	Co	Fe	Pb	Mg	Mn	Hg	Ni	K	Na	Sn	V
EL-1	Middle	15	284	-	16	55	4380	-	4.5	-	577	-	2260	46	-	13	2020	7690	-	-
EL-2	Surface	21	318	-	19	56	4740	-	-	-	577	-	2490	51	-	6.9	2240	7670	-	-
EL-2	Bottom	22	288	-	26	56	4830	-	3.4	-	929	-	2430	54	-	10	2060	7490	-	-
EL-3	Surface	17	303	-	17	53	4730	-	-	-	561	-	2400	53	-	9.1	2280	8610	-	-
EL-3	Bottom	18	346	22	19	52	4670	-	3.3	-	760	-	2340	60	0.38	11	2100	7810	-	-
EL-5	Surface	14	458	-	15	54	4580	-	4.8	-	642	-	2460	53	-	11	2330	7360	-	-
EL-5	Bottom	10	462	-	22	53	4460	-	4.4	-	757	-	2400	53	-	9.7	2370	7260	-	-
EL-8	Surface	10	469	-	16	49	4070	-	5.8	-	743	-	2090	56	-	16	2010	586	-	-
EL-8	Bottom	18	661	-	17	50	3890	-	4.2	-	839	-	2120	56	-	14	2100	6070	-	-
EL-25	Surface	14	324	-	20	54	4490	-	5.8	-	564	-	2370	52	-	16	2070	6060	-	-
EL-25	Bottom	16	325	-	16	49	4380	-	-	-	612	-	2210	50	-	11	2200	6900	-	-
EL-26	Surface	14	417	-	14	52	4360	-	3.5	-	649	-	2320	55	-	6.8	2180	6060	-	-
EL-26 (D)	Surface	15	411	-	17	54	4470	-	5.9	-	711	-	2370	62	-	6.7	2310	5980	-	-
EL-26	Bottom	15	909(R)	-	98(R)	66	4670	-	13	-	-	15	2440	113(R)	-	8.4	2140	7080	-	7.5
EL-26 (D)	Bottom	14	427(R)	-	15(R)	53	4450	-	-	-	657	-	2340(R)	54	-	8.4	2170	6100	-	-
EL-27	Surface	15	484	-	16	53	4450	-	3.2	-	711	-	2370	55	-	-	2190	6150	-	-
EL-27	Bottom	15	2250	17	126	92	4900	-	21	4.6	6580	24	2430	117	0.26	13	1850	6040	-	15
EL-28	Surface	21	255(R)	15	20	53	4670	-	6.0	3.7	556	-	2330	50	12	12	2070	6990	-	-
EL-28	Bottom	41	981	40	187	69	4910	-	9.7	4.7	5760	12	2390	78	-	11	2180	6390	18	11
EL-29	Surface	24	310	-	39	57	4750	2.0	3.5	-	1220	-	2390	56	-	-	2070	7610	-	-
EL-29	Bottom	23	286	-	34	56	4840	-	4.1	4.6	1030	-	2400	55	-	9.9	2080	750	-	-
EL-30	Middle	23	303	-	24	56	4760	-	-	-	261	-	2490	53	-	18	2110	7630	14	-

Dashes indicate the parameter was not detected.
(R) - Rejected value
(D) - Duplicate analysis

6242b

4.2.3 Ebasco Phase II Results

Twenty-two water samples were collected during Phase II. These samples were analyzed for dissolved arsenic and HSL inorganic parameters. The sampling stations are shown in Figure 4-1, with the results presented in Table 4-6.

The water samples (10 bottom, 10 surface, 2 mid-depth) were analyzed for dissolved arsenic. Dissolved arsenic concentrations ranged from 10-41 ug/l, with a median value of 16 ug/l. This range is consistent with the NJDEP winter sample results for Union Lake. Thus, the Phase II data lends further support to a seasonal pattern of arsenic concentrations in Union Lake.

All of the Phase II water samples were also analyzed for HSL inorganics from unfiltered field aliquots. A total of 18 HSL metals were detected. Principal components of the lake water were arsenic (16 - 187 ug/l), aluminum (285 - 2250 ug/l), calcium (4070 - 4910 ug/l), iron (556 - 6580 ug/l), magnesium (2090 - 2490 ug/l), manganese (50 - 117 ug/l), potassium (1850 - 2280 ug/l), barium (49 - 92 ug/l) and nickel (ND - 18 ug/l). Also present in trace amounts and generally associated with bottom water were chromium (ND-21 ug/l), mercury (ND-0.38 ug/l), lead (ND-24 ug/l), cobalt (ND-4.7 ug/l), cadmium (ND-2 ug/l), antimony (ND-40 ug/l), vanadium (ND-15 ug/l) and tin (ND-14 ug/l).

The Phase II sampling and analytical precision, as evident by the duplicate results, (except for the bottom water duplicate, EL-26) was good. This was not unexpected since the increased contribution of resuspended bottom sediments in the bottom water samples would cause greater variability in the analytical results.

Brief summary tables of the concentration ranges for arsenic in Union Lake sediments and water are presented in Table 4-7 and 4-8, respectively.

4.3 CONSIDERATIONS FOR REMEDIAL ALTERNATIVES

Based on the Phase I and Phase II findings and on the findings of the studies conducted by the NJDEP, the sediment in Union Lake is extremely heterogeneous in physical and chemical composition. The percent of sand and silt varied greatly between samples collected in close proximity to one another. Similarly, the arsenic concentrations in collocated samples varied by orders of magnitude.

Arsenic contamination, as evidenced by the core sample analytical results, is a surficial phenomenon, present in the first one foot of the Union Lake sediments. Concentration levels ranged from not detected to 1,273 mg/kg, with the greatest levels occurring within the northern portion of the lake. Most of the detected concentrations were below 50 mg/kg, as shown in Figure 4-4.

TABLE 4-7

CONCENTRATION RANGES (mg/kg) OF TOTAL ARSENIC LEVELS IN UNION LAKE SEDIMENT SAMPLES

	Total As
NJDEP SAMPLING (August, 1986)	
Lakeshore sediments in less than 10 feet of water (193 sample locations)	0 - 1273
PHASE I (June - July, 1986)	
Upper Lake sediment (EL-1, EL-2)	36 - 65
Mid-Lake sediment (EL-5)	12
Lower Lake sediment (EL-9 through 13)	14 - 107

TABLE 4-8

CONCENTRATION RANGES (ug/l) OF TOTAL, DISSOLVED AND PARTICULATE ARSENIC IN UNION LAKE WATER SAMPLES

	Dissolved As	Particulate As	Total As
NJDEP (September, 1982-1983)			
Upper Lake water	-	-	36 - 267
Mid-Lake water	-	-	27 - 100
Lower Lake water	-	-	33 - 194
PHASE I (June - July, 1986)			
Upper Lake water (EL-1, EL-2)	44(R) - 50(R)	16 - 21	65(R) - 66(R)
Mid-Lake water	48 - 67	3.8 - 9.9	54 - 71
Lower Lake water (EL-9 through EL-13)	48 - 75	5 - 10.2	54 - 81
PHASE II (January, 1987)			
Upper Lake water (EL-28 through EL-30)	21 - 41	NA	20 - 187
Mid-Lake water	10 - 22	NA	11 - 26
Lower Lake water (EL-9 through EL-13)	14 - 16	NA	12 - 126

NA - Not Applicable or Available
(R) - Rejected value

Earlier works by the NJDEP showed a positive correlation between percent silt-clay, total organic carbon, and arsenic concentrations within the Maurice River drainage basin. No such relationship was seen in Union Lake percent sand and arsenic values from the 1986 sediment sampling. However, the grain size data from this sampling event may be suspect. The percent silt and percent clay contents were not determined along with the percent sand content of these samples, therefore there is no means to check the total recovery as an indication of the analytical accuracy of the sizing. Nevertheless, positive correlations between arsenic levels and percent silt-clays and/or total organic carbon are speculated to be present. A positive correlation between arsenic and TOC and between arsenic and fine grain sized material was seen in the river areas upstream from the lake (Ebasco, 1986).

The results of the Union Lake water sampling and analyses indicate that trace metals (Sb, Co, Hg, Sn, V) were usually present only in the unfiltered water samples collected at the bottom of the water column, at the sediment-water interface. This result suggests that these metals are associated with resuspended bottom sediments. These sediments may become part of the near bottom water column and consequently may be present within the unfiltered water samples, but may not normally be part of the water column farther above the sediment/water interface. This contention is supported by the fact that trace metals have been detected in the Union Lake sediments and in unfiltered water samples taken at the sediment/water interface, while the same trace metals appear less frequently in unfiltered water samples taken at the surface or in the middle of the water column. Also, dissolved arsenic concentrations were fairly consistent throughout the water column (surface, middle and bottom).

Union Lake water is contaminated with arsenic (10-187 ug/l) and apparently exhibits seasonal fluctuations in arsenic levels. The greatest levels occur in summer and early fall, and the lowest levels occur in winter. This seasonality in arsenic concentrations is supported by several studies. Resuspended lake sediment can cause elevated arsenic concentrations and can introduce other trace metals into the water column, particularly close to the bottom and in highly turbid areas of the lake (i.e., adjacent to the point at which the Maurice River enters the northern portion of the lake).

Union Lake Dam at the southern end of the lake presents a safety hazard due to a severely inadequate spillway and embankment stability (PRC Engineering, 1986). Construction activities are currently underway to demolish the existing spillway and reconstruct a new auxiliary spillway and downstream channel. This work has required a breaching of the dam and partial dewatering of the lake. The pool elevation was lowered by eight to nine feet, resulting in the exposure of 50 to 105 acres of lake sediment, particularly within the northwestern, northern and northeastern sections of Union Lake (PRC Engineering, 1986).

Since the sediment sampling was performed in 1986, the lake's water level has been lowered. Also, the submerged dam at the northern end of the lake has been breached. Both of these events may have caused some redistribution of sediments in the lake. Also, since the lake is a dynamic system, the sediments may naturally redistribute owing to current patterns. Before implementing any remedial action in the lake, sediments should be resampled to see what effect natural or man-made processes may have had on the contaminated sediment distribution within the lake.

In summary, considerations for remedial alternatives for Union Lake are as follows:

- The sand, clay, and silt contents of the sediments vary greatly throughout the lake.
- Arsenic concentrations in sediments are highly variable and frequently show heavy contamination (not detectable to 1,273 ug/kg).
- Arsenic sediment contamination is widespread across much of the lake bottom in both deep and shallow (less than ten feet deep) areas.
- Sediment contamination tends to be a surficial phenomenon, occurring in the top one foot of sediment.
- The greatest levels of arsenic are generally found in the northern portion of the lake.
- Relationships are believed to exist between arsenic levels and percent silt-clay content and/or total organic carbon content in the sediment, based on the past NJDEP data.
- The presence of trace metals in the bottom of the water column is speculated to be due to the resuspension of bottom sediments.
- Dissolved arsenic concentrations are fairly consistent throughout the water column. However, resuspension of lake sediment during dredging operations can cause elevated arsenic levels and introduce other trace metals into the water column.
- Due to the current construction on the Union Lake dam and the resulting lowering of the lake level by approximately eight to nine feet, 50-105 acres of the lake bottom will be exposed until approximately June 1990. Remedial alternatives for the contaminated sediments should include remediating the sediment contamination after the lake has been refilled, due to the likely timing of potential remedial actions.

Union Lake is part of a dynamic system. The other RI reports prepared for the Plant Site and the River Areas detailed what is known about the mass balance of arsenic in the watershed, which will also influence how and when remediation is undertaken in the lake. The River Areas RI report (Ebasco, 1989c) provides the most comprehensive description of arsenic mobility in the watershed downstream from the plant site.

5.0 BIOTA INVESTIGATION

5.1 APPROACH

The biota investigation of Union Lake was conducted by Ebasco during Phase II in January, 1987. Fish were collected, prepared for shipment, and analyzed in accordance with the Phase II Field Operations Plan. The objective of the fish investigation was to collect data specifically for risk assessment (Section 7.0). These data were used to characterize the potential health risks associated with the ingestion of fish caught in Union Lake.

5.1.1 Sampling Locations

Fish were collected from three locations in Union Lake. Sample station ELB-1 was located in the northern portion of the lake approximately 500 feet behind the submerged dam. Station ELB-2 was chosen as a mid-lake sample location, and ELB-3 was located approximately 800 feet behind Union Lake Dam in the southern portion of the lake. Sample locations were shown in Figure 4-1. The depths of the water at sample stations ELB-1, ELB-2, and ELB-3 were 5.5, 10, and 19 feet, respectively.

5.1.2 Sampling Methods

Fish were caught in trammel nets which were approximately five feet high and 110 feet long. The nets were set on the lake bottom. Therefore the net spanned the entire water column at station ELB-1. At ELB-2, the net covered the lower half of the water column. At ELB-3, the net covered only the lowest portion of the water column.

Three nets were set, one at each location, on the same day. The catch at ELB-3 was retrieved after approximately 24 hours. The catches at ELB-1 and ELB-2 were retrieved after approximately 40 hours.

Five species of fish were obtained. Pickerels were caught at ELB-1, sunfish and suckers at ELB-2, and two species of catfish at ELB-3. The fish were identified in the field by the project biologist and segregated as the nets were retrieved.

The fish samples were prepared by decapitating, scaling, gutting, and filleting each of six to seven fish of the same species. The muscle tissue, with the skin on, from the left side of each individual was combined into one sample of each species. The same side of each fish was used for the sample to avoid systematic sampling errors resulting from different contaminant accumulation rates on different sides of individual fish.

Each of the five fish samples (one of each species mentioned above) were shipped to a CLP laboratory for total arsenic, pesticide, and PCB analyses. The pickerel sample was split into two separate samples to obtain duplicate analyses.

5.1.3 Quality Assurance and Quality Control

The knives used for preparation of the fish samples were initially decontaminated and then decontaminated again after the preparation of each sample of each species. Decontamination consisted of an Alconox wash, potable water rinse, acetone rinse, and a final deionized water rinse. The knives were allowed to air dry after the final deionized water rinse.

Two field blanks were collected from the knives used to prepare the fish samples. The blanks were prepared by pouring deionized water over the decontaminated knives. The field blanks were obtained to document that cross-contamination had not occurred during the preparation of the samples. Trip blanks were not prepared as none of the fish samples were shipped for volatile organic analyses.

5.2 FIELD INVESTIGATION RESULTS

The results of the fish analyses are presented in Table 5-1. Among the fish caught, chlordane (5-72 ug/kg), DDE (63-160 ug/kg), PCB 1260 (120-400 ug/kg) and arsenic (20-240 ug/kg) were found to be present. The results indicate that the greatest concentrations of each chemical compound were generally present within bottom feeding (i.e., catfish) and piscivorous species (i.e., pickerel). These results are consistent with similar studies of pesticide/PCBs and/or metal residues within fish muscle tissue performed elsewhere (USEPA, 1976). The duplicate sample results show that the precision of the analytical results was very good.

The results of the investigation of the contaminant levels of the fish of Union Lake are discussed in the risk assessment (Section 7.0).

TABLE 5-1

ARSENIC, PESTICIDE AND PCB RESULTS
FOR FIVE FISH SPECIES (ug/kg)
(January, 1987)

Organism	Chlordane	4,4'-DDE	Arochlor 1260	Arsenic
Catfish species 1 (*Ictalurus sp.*)	72	160	400	220
Catfish species 2 (*Ictalurus sp.*)	54	89	200	110
Sucker (Family catostomidae)	32*	63	120	20**
Sunfish (*Lepomis sp.*)	5*	-	-	20
Pickerel (*Esox sp.*)	7*	-	-	240
	7*(d)	-(d)	-(d)	190(d)

\- - Not detected
* - Below detection limit
NA - Not applicable or available
** - Less than concentration listed
(d) - Duplicate sample result for *Esox sp.*

6.0 BENCH-SCALE TREATABILITY TESTS

The bench-scale treatability studies for the arsenic-contaminated sediments from the lake were conducted to produce adequate data for the evaluation of the technical feasibility and cost-effectiveness of the treatment processes tested. Based on the general feasible technologies for arsenic treatment in sediments, the following bench-scale tests were proposed to be conducted:

- Chemical fixation and solidification test; and
- Chemical extraction of arsenic from sediments test.

The fixation test was conducted by Lopat Enterprises, Inc., and the extraction test was performed by Hittman Ebasco Associates Incorporated (HEAI) during the summer and fall of 1987.

Each of these two bench-scale tests is discussed separately in the following subsections. For each test, the discussion covers the testing objectives, description of the test, the results and the conclusion. The laboratory testing materials (e.g., sediments), apparatus, procedures, and results of the bench-scale tests performed by Lopat and Hittman are presented, respectively, in Appendix B and C of this report.

6.1 SEDIMENT FIXATION TEST

Sediments contain total arsenic concentrations in the range of not detected to 1,273 mg/kg. Four arsenic species contained in the sediments are As (V), As (III), monomethyl arsenic acid (MMAA) and dimethyl arsenic acid (DMMA). The inorganic arsenate is approximately 75% of the total arsenical species. The sediment sample for the chemical fixation tests was a composite. One-half was collected from the on-site unlined lagoon which receives treated wastewater and non-contact cooling water discharge, and the other half was collected from the Blackwater Branch. The composite sample was obtained on August 14, 1987. The sample tested was a composite sample with equal volumes of sample collected from both areas.

6.1.1 Objectives

The purpose of conducting the fixation test was to confirm whether arsenic in the sediments could be chemically stabilized or physically bound to the sediment such that leachable arsenic was reduced after performing the RCRA Extraction Procedure Toxicity Test (EPTOX) to a level below 5 mg/l of total arsenic. At the time of the test, it was believed that if the treated material passed this criterion, it would be considered non-hazardous and could be disposed in a non-hazardous waste landfill. Subsequent guidance has been received on the requirements to consider the treated materials non-hazardous. These requirements are discussed in detail in the Union Lake FS (Ebasco, 1988e).

6.1.2 Description of Test

The fixation test consisted of four sequential tasks:

- Sediment characterization;
- Chemical fixation and solidification with different formulations;
- Unconfined strength (UCS) test and RCRA Extraction Procedure (EP) toxicity test; and
- USEPA Multiple Extraction Procedure (MEP) test.

Sediment Characterization

The sediment sample was analyzed for total arsenic content and total organic carbon content to determine whether the sample was representive and suitable for testing. The sample was found to contain total arsenic of 320 mg/kg which was representative of the arsenic concentration of the sediments in the lake.

Fixation and Solidification

Three samples were treated using three formulations in an attempt to economically transform the sediment into materials which would meet the performance criteria (e.g., leachable concentration below 5 mg/l of total arsenic and 1,500 lbs/ft^2 of UCS).

A commercial silicated blend known as K-20/LSC Lead-in-Soil Control System developed and manufactured by Lopat Enterprises, Inc. of Wanamassa, New Jersey was selected because of its ability to be custom-blended as needed for a particular application. In addition, the K-20/LSC System has been demonstrated and proven to be effective for essentially all of the toxic metals (e.g., Pb, Ba, Cd, Cr, As, Hg, etc.). Although to a lesser degree, K-20/LSC has also been proven to be effective for certain organic compounds such as PCBs.

As shown in Table 6-1, the three samples were chemically fixed and solidified using three different mixtures of chemicals (such as Darco Gro-Safe Activated Carbon), additives (Type 1 Portland cement, lime, and Type F fly ash) and proprietary reagents (K-20/LSC). The treated samples were allowed 48 hours curing and drying.

UCS Test and EP Toxicity Test

The treated samples were tested for Unconfined Strength (UCS) during the 48-hour curing and for the EP Tox (40 CFR 261.24) after curing for 48 hours.

TABLE 6-1

SUMMARY OF TREATABILITY TESTS FOR THE CHEMICAL FIXATION AND SOLIDIFICATION OF ARSENIC IN SEDIMENT

SAMPLE NUMBER	SAMPLE TREATMENT	USC (lbs/ft^2)	VOLUME CHANGE (%)	TOTAL ARSENIC CONCENTRATION: EP TOX TEST (mg/l)	Multiple Extraction Procedure (MEP Tests (mg/l): 1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1. 1106-84-02	400 grams of Sediment + 0.5%* K-20 LSC **+ 2% Darco Gro-Safe Activated Carbon + 36% Type I Portland Cement + 12% Type F Fly Ash.	9,000	-34	1.5	0.02	0.14	0.12	0.07	0.07	0.08	0.05	0.07	0.09	0.12
	Results of Confirmatory Analyses	-	-	0.80	0.32	0.20	0.08	0.05	0.05	0.06	0.05	0.05	0.06	0.06
2. 1106-85-01	400 grams of Sediment + 0.5% K-20 LSC + 2% Darco Gro-Safe Activated Carbon + 40% Lime + 20% Type I Portland Cement + 20% Type F Fly Ash.	8,000	- 2	1.2										
3. 1106-85-02	400 grams of Sediment + 0.5% K-20 LSC + 2% Darco Gro-Safe Activated Carbon + 60% Lime + 60% Type F Fly Ash.	600	+70	1.0										

* Percentage of sample weight.

** K-20 is a silicate based fixation reagent and a proprietary reagent of Lopat Enterprises, Inc. LSC (K-20 Lead-in-soil Control System).

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MEP Test

The tested sample which best complied with the established performance criteria was further tested by the USEPA Multiple Extraction Procedure (MEP) to estimate the long-term stability of the treated material under conditions simulating 1,000 years of exposure to acid rain (47 CFR 52686-87, November 22, 1982). If the solidified sample complied with the leachable concentration of 5 mg/l for all ten sequential extractions, a duplicate treated sample would be prepared to demonstrate the reproducibility of the treatment.

6.1.3 Results

As shown in Table 6-1, all three treated samples meet the performance criteria of fixation and solidification except Sample 1106-85-02 which failed to meet the UCS requirement (i.e., 1,500 lb/ft^2). The leachable arsenic concentrations resulting from the EP TOX tests were in the range of 1.0 mg/l to 1.5 mg/l.

Sample 1106-84-02 consisted of sediment, K-20/LSC, activated carbon, Portland cement and fly ash. Since the fixation required water, no dewatering was required for the sediments other than decanting of the supernatant. After 48 hours of curing, the mixture passed the RCRA EP toxicity test and its unconfined compressive strength reached 9,000 pounds per square foot (lbs/ft^2) as measured by the ASTM unconfined strength test. This strength is higher than the 1500 lbs/ft^2 generally required for landfilling and is sufficient to support truck traffic and other earth moving equipment. The sediment-mixture volume was only 34 percent of the original sediment volume due to the drying and solidification of the sediments. Costs for a full-scale fixation operation were estimated to be $150 to $200 per cubic yard of sediment.

Sample 1106-85-01 reacted similarly to Sample 1106-84-82 although lime was also added to the mixture. The mixture passed the EP TOX test and had an unconfined compressive strength of 9,000 lbs/ft^2. There was substantially no change in the mixture volume after drying and solidification. The cost for a full-scale operation was estimated to be $175 to $225 per cubic yard of sediment.

Sample 1106-85-02 reacted similarly to Sample 1106-85-01 but Portland cement was not used in the mixture. The mixture passed the EP TOX test and resulted in 600 lbs/ft^2 of unconfined strength, below the performance criteria of 1,500 lbs/ft^2. The mixture volume increased 70% over the sediment volume. Costs for a full-scale operation were estimated to be $200 to $250 per cubic yard of sediment.

Sample 1106-84-02 was found to be the most promising of the three test formulations and was therefore selected to undergo MEP testing. The selection was made based on the consideration of cost-effectiveness and the potential for volume reduction. As shown in Table 6-1, the leachable arsenic concentrations from the MEP test were in the range of 0.02 mg/l to 0.15 mg/l which is far below the toxicity criterion of 5 mg/l. All ten sequential extractions performed as part of the MEP test passed the toxicity criterion. A duplicate treated sample was then prepared for MEP testing. This duplicate sample also passed the MEP test and demonstrated the reproducibility of the treatment.

The K-20/LSC System is an inorganic silicate-based material that is non-toxic, non-hazardous, and easy and safe to apply. The major functions of the K-20/LSC System which contribute to the successful fixation and solidification of arsenic compounds are:

- Precipitation of heavy metals contaminants;
- Encapsulation of heavy metals contaminants; and
- Protection and stabilization of encapsulated metal contaminants from acid (rain).

6.1.4 Conclusion

Based on these laboratory results, it is concluded that the arsenic compounds in the lake sediments can be chemically stabilized to well below the original target criterion of 5 mg/l leachable arsenic. The application of fixation to the sediments, and the new target criteria for disposal, are discussed in detail in the Union Lake FS Report.

6.2 ARSENIC EXTRACTION FROM SEDIMENT TEST

The sediment sample for the arsenic extraction tests was a composite, with one-half collected from the on-site unlined lagoon which receives treated wastewater and non-contact cooling water discharge, and the other half collected from the Blackwater Branch on July 17, 1987. The sample tested was a composite sample with equal volumes of sample collected from both areas.

6.2.1 Objectives

The primary purpose of the chemical extraction tests was to obtain performance data on the extraction of arsenic oxides and methylated arsenic oxides from the sediments. The performance criterion required that the treated sediment contain a total arsenic concentration below 20 mg/kg [the arsenic cleanup level in the New Jersey Environmental Cleanup Responsibility Act Standards (ECRA, NJAC 7:26B-1.1 et seq.)]. This target level was established at the beginning of the investigation. Subsequent guidance has been received concerning the criteria for non-hazardous disposal of the extracted sediments. The new requirements are discussed in detail in the Union Lake FS Report (Ebasco, 1988e).

In addition, the results of this test provided the data to determine the amount of and costs for chemicals required for successful extraction. This information is needed for determining the economic feasibility of extracting arsenic from sediments.

6.2.2 Description of Test

The chemical extraction test consisted of three sequential tasks:

- Sediment characterization;
- Comparison of extraction reagents; and
- Evaluation of pH and temperature effects on arsenic removal.

Sediment Characterization

The sediment sample was analyzed for total arsenic content and total organic carbon content to determine whether the sample was suitable for testing. The sample was found to contain total arsenic of 2,780 mg/kg. The sample represented the worst case arsenic concentrations that may be expected to be found in the lake sediments.

Comparison of Extraction Reagents

The sample was decanted for supernatant only and did not require any further dewatering. The sample was extracted with water, with and without added chelating compounds. Sodium citrate, sodium oxalate, and ethylenediaminetetra-acetate (EDTA), all commonly used extracting agents, were the three chelating reagents tested. A 200 gram sample was added with 200 ml of aqueous reagent to form a slurry. The slurry was stirred continuously for two hours at a speed of 40 rpm. The treated samples were allowed to settle and then were analyzed for total arsenic and total organic carbon. The tests for the chelating reagents evaluation were conducted at room temperature and a pH of 7.0.

Evaluation of pH and Temperature Effects on Arsenic Removal

The samples were extracted with water at different pH levels to determine the optimal pH for arsenic extraction. Sodium hydroxide and hydrochloric acid were used to adjust the samples from near-neutral condition to acid and alkali conditions. The samples were extracted with water at pH levels of 7.0, 12.0, and 3.0.

The chelating reagent which appeared most effective in removing arsenic compounds was used for extraction at different temperatures (24°C and 50°C) and different pH levels (5.0 and 7.0). Due to the very high organic content (70,000 mg/l) of the sediment, a very large amount of NaOH was required to maintain the extraction at a high pH level.

6.2.3 Results

As shown in Table 6-2, extraction without a chelating reagent did not remove arsenic from the sediments below the performance criterion (i.e., 20 mg/kg of total arsenic) at room temperature or near-neutral pH. Chelated extraction with sodium citrate seemed to work best at removing arsenic under these conditions. After washing (to remove any residual reagent), the extracted sludge contained 21 mg/l of total arsenic which almost achieved the target arsenic concentration of 20 mg/l of total arsenic. It should be noted that the chemical extraction process generated a significant amount of suspended fine organic particles which almost equal 90% of the TOC contained in the original sediment sample. Most of the suspended organic particles could not be removed by gravity sedimentation.

With the exception of extreme alkali conditions (i.e., pH of 12.0) the pH effects on the removal of arsenic from sediments were insignificant. The experiment revealed that extremely large amounts of NaOH were required to maintain the pH at a constant value of 12. For example, 400 ml of 5N NaOH were not sufficient to keep the pH at 12 through the two-hour extraction of a 200 ml slurry. This phenomenon was probably due to the very high organic content of the sediment.

The experiment indicates that high temperature did not result in any improvement in arsenic extraction. In fact, the extraction at high temperature (50°C) removed less arsenic from the sediments than at room temperature (24°C). Therefore temperature is not an important factor in the chemical extraction treatment process.

Costs for a full-scale operation of arsenic extraction processes utilizing sodium citrate were estimated to be $100 to $150 per cubic yard.

6.2.4 Conclusion

Based on these laboratory results, it is concluded that the target arsenic concentration (below 20 mg/kg of total arsenic) could be achieved for the sediments by chemical extraction with the citrate chelator at a pH range of 5 to 7 at room temperature (24°C). Water extraction achieved a level of 34 mg/kg arsenic, a substantial reduction from the incoming concentration of 2780 mg/kg. Extraction, and the new target criteria for disposal, are discussed in the Union Lake FS (Ebasco, 1989f).

TABLE 6-2

SUMMARY OF TREATABILITY TESTS FOR THE EXTRACTION OF ARSENIC FROM SEDIMENT

Sediment Characterization

Sample Number	Untreated Sediments Total As (mg/kg)	TOC (mg/kg)
833-039-03	2,780	70,000

Selection of Chelating Reagents

Sample Number		Treated Sediments* Total As (mg/kg)	TOC (mg/kg)
836-003-03	No Chelator, pH = 7.0, 24°C	36	513
836-005-01	Sodium Citrate 3,170 mg/l, pH = 7.0, 24°C	21	635
836-005-02	Sodium Oxalate 3,490 mg/l, pH = 7.0, 24°C	45	953
836-005-03	EDTA (Tetrasodium Salt) 1,440 mg/l, pH - 7.0, 24°C	37	506

pH Effects

Sample Number		Treated Sediments* Total As (mg/kg)	TOC (mg/kg)
836-003-03	No Chelator, pH = 7.0, 24°C	36	513
836-003-04	No Chelator, pH = 12.0, 24°C	14	488
836-003-05	No Chelator, pH = 3.0 24°C	36	833

* Performance criterion total As concentration of less than 20 mg/kg.

TABLE 6-2 (Cont'd)

SUMMARY OF TREATABILITY TESTS FOR THE EXTRACTION OF ARSENIC FROM SEDIMENT

pH and Temperature Effects

Sample Number		Treated Sediments Total As (mg/kg)	TOC (mg/kg)
836-007-01	Sodium Citrate 3,170 mg/l, pH = 5.0, 24°C	21	756
836-008-01	Sodium Citrate 3,170 mg/l, pH = 7.0, 50°C	44	2,650
836-008-02	Sodium Citrate 3,170 mg/l, pH = 5.0, 50°C	32	1,460

7.0 PUBLIC HEALTH AND ENVIRONMENTAL CONCERNS

A public health evaluation of the contamination in Union Lake, primarily arsenic contamination, was performed with two objectives. The first was to assess the potential health risks to exposed populations associated with Union Lake in its normal condition. The second was to determine any increased risks resulting from the lake in its drawdown condition, i.e., when the lake was partially drained to repair the dam. This lake drawdown and dam repair began in the late spring of 1987 and is expected to take three years to complete. To ensure a thorough evaluation, all pertinent data and information collected during Ebasco's Phase I and Phase II sampling efforts and the NJDEP's 1986 sediment sampling program have been used.

Once the nature and extent of potential public health threats are determined from a baseline risk assessment (i.e., No Action alternative), a decision may be made whether a site requires remedial action and what remedial objectives would be most appropriate.

7.1 PUBLIC HEALTH METHODOLOGY

The public health evaluation methodology utilized in this study follows the Superfund Public Health Evaluation Manual, OSWER DIR 92854-1, October 1986. The first step was the identification of chemical contaminants in Union Lake of concern to public health and the environment. Indicator chemicals were selected as per EPA guidances, principally by toxicological and physico-chemical properties and known or expected environmental effects. The next step identified possible exposure pathways and receptors at risk. The pathways were screened for applicability to the site and site-specific scenarios were developed to more completely define the exposures. Two sets of exposure pathways were developed; one to estimate worst case exposures and one to estimate the most probable exposures.

The highest measured pollutant values in the various media were used to calculate the worst case exposure. A data quality analysis to determine the most representative contaminant concentrations by media and season was conducted for the most probable scenario. These values were used in the critical exposure pathways to calculate the risks. Finally the remedial objectives were determined from the critical pathways.

7.1.1 Hazard Identification

Chemical contaminants used in the risk assessment were selected based upon levels detected in Union Lake and upon toxicological, physical and chemical characteristics of the contaminants. In addition to comparing the detected levels to naturally occurring background levels (Table 7-1), the chemicals were also compared to those used, manufactured or stored at the ViChem plant (Table 1-2).

TABLE 7-1

A COMPARISON OF BACKGROUND METAL CONCENTRATIONS AT THE VINELAND SITE WITH NJ LAKEWOOD AND TYPICAL U.S. SOILS

Metal	Background Level in Site Soils Depth 5 to 120 ft[a] Mean and Std Dev mg/kg	Number of Samples	No. of Estimated Values in Mean	Range of Measured Values mg/kg	Range of metals in a NJ Lakewood Type Soil[b] mg/kg	Typical Range of Sandy Soil in the U.S.[c] mg/kg
Al	744 ± 527	8	2	432 - 1780		0.45 to 10^5 [d]
Sb	18.4 ± 11.4	8	0	7.3 - 39		0.05 - 4.0[d]
As	3.27 ± 1.77	7	1	1.2 - 5.3		0.1 - 30
Cr	6.15 ± 3.67	8	1	2.0 - 12	5.0 - 10.0	3 - 200
Co	6.01 ± 4.04	8	1	1.6 - 11	0.5 - 1.1	0.4 - 20
Cu	3.56 ± 1.12	8	1	2.0 - 5.8	0.5 - 1.1	1 - 70
Fe	4710 ± 3550	7	0	599 - 9995		
Pb	2.39 ± 0.87	7	1	1.1 - 3.25	10 - 30	<10 - 70
Mn	6.83 ± 4.55	7	4	1.7 - 15		7 - 2000
Hg	0.10 ± 0.004	7	0	0.1 - 0.11		0.01 - 0.54
Ni	7.74 ± 4.87	8	1	1.3 - 15	11.1 - 13.1	5 - 70
Se	1.67 ± 0.87	8	0	0.45 - 3.0		0.005 - 3.5
Zn	10.0 ± 6.49	8	1	4.8 - 23	4.5 - 10.0	<15 - 164

a Ebasco Soil Samples, RI for ViChem Plant site (Ebasco, 1989a).

b Tedrow, J.F.F. 1987, Soils of New Jersey, R.E. Krieger Publisher, Melbourne, FL.

c Kabata-Pendias, A. and H. Pendias, 1984, Trace Elements in Soils and Plants, CRC Press Inc.,Boca Raton, FL.

d Values are from a range of all soil types, not just sandy soils. From Kabata-Pendias and Pendias, 1984.

7.1.1.1 Organic Chemicals

The sediment and lake water samples were analyzed for HSL inorganics, arsenic (dissolved and total), and volatile organics, but not for semi-volatiles, pesticides or PCBs. No volatile organics were detected. Pesticides and PCBs were analyzed in the fish caught at Union Lake. Three organic chemicals were detected in fish (Chlordane, 4,4'DDE, and Arochlor 1260) as shown in Table 5-1. None of these chemicals are related to those manufactured or used at ViChem. Chlordane and 4,4'DDE (the primary degradation product of DDT) are very persistent chemicals and are associated with widespread use of pesticides in rural and agricultural areas. Since the region in which Union Lake is located is rural and agricultural, such compounds are not unexpected. Arochlor 1260 is a common polychlorinated biphenyl which is very persistent and has been found in many rivers and streams.

Since there is no information on the presence of these organic chemicals in sediment or lake water, these chemicals were not evaluated in any pathways involving water or sediment. However, chlordane, 4,4'DDE and Arochlor 1260 are carcinogens, and since the carcinogenic risks are considered additive in public health risk assessments, the risks associated with the ingestion of fish were calculated for these chemicals.

7.1.1.2 Inorganic Chemicals

In selecting indicator metals to characterize the public health risks, metals were compared to background levels (Table 7-1) and to those associated with ViChem. Arsenic, cadmium, mercury, calcium, sodium, iron, and aluminum are known to have been used by ViChem. Arsenic was detected in the sediment, water, and fish samples at significant levels by Ebasco and NJDEP (Tables 4-3, 4-4, 4-5, 4-6, 4-7, 4-8 and 5-1). Because of its use at ViChem, widespread detection at high concentrations and its toxicological properties, arsenic was selected as an indicator chemical for the risk assessment.

Cadmium was not detected in the sediment samples, but was detected twice in 28 water samples analyzed for HSL inorganics at 2 ug/l and 5.8 ug/l. Mercury was not detected in the two sediment samples, but was detected in four out of 28 water samples analyzed for HSL inorganics at relatively low levels (0.38, 0.26, 0.3, and 12 ug/l). Neither mercury nor cadmium were found in the Blackwater Branch or Upper Maurice River water or sediments; however, both were detected in the groundwater at the ViChem plant area and both were used at the chemical plant in the manufacture of herbicides. In addition, mercury was also found in the subsurface soils at the ViChem plant. Therefore, mercury was also chosen initially as an indicator chemical.

Calcium, sodium, iron and aluminum were all used at the chemical plant and were detected in water and sediment samples. Their detections were not at levels high enough to result in adverse health effects nor were they significantly above background levels.

Other metals, not associated with ViChem, were detected at trace concentrations either in samples of water, sediment or both and are listed in Table 7-1. Antimony was detected in several samples in which there were high levels of sodium. This detection may be an artifact of the laboratory analysis, especially if atomic absorption was the detection method. None of these are at concentrations high enough to result in adverse health effects nor are they significantly above background levels. Lead, beryllium, vanadium and zinc were detected in one of the two sediment samples. Because only two sediments samples were analyzed for the full HSL inorganic chemicals, it is difficult to say if these detections are statistically significant. Of these elements, lead is the most toxic and was found in three water samples taken from the bottom of the lake. These bottom water samples were not filtered and may have contained sediment. Thus lead was selected as a non-carcinogenic indicator chemical for the lake sediment.

7.1.2 Toxicological Summary

The purpose of this section is to identify the health and environmental hazards associated with the selected indicator compounds. The indicator compounds represent the greatest public health and environmental concerns associated with Union Lake.

In the toxicological evaluation in Section 3, the inherent toxicity of arsenic was described by reviewing the scientific data to determine the nature and extent of health and environmental hazards.

It was noted in Section 3 that past studies showed arsenic existed primarily in four forms in Union Lake: As (III), As (V), MMAA, and DMAA. The most toxic of these forms is As (III). In this investigation, the form of the arsenic detected in the sediments, surface water, and fish was not determined. Total arsenic analyses were performed. Therefore, unless otherwise noted, in this risk assessment it is assumed that all of the arsenic is speciated in a manner similar to that encountered in the epidemiologic studies used to define the toxicologic parameter (carcinogenic potency factor) for inorganic arsenic.

Toxic effects include noncarcinogenic effects, in which a certain dose is required to result in a particular adverse effect (either subchronic or chronic), carcinogenic effects to which any exposure could potentially be associated with adverse health implications, and environmental effects (acute and chronic toxic effects) observed in aquatic biota and/or terrestrial wildlife.

Toxicity summaries for the indicator compounds of arsenic, mercury and lead are presented in Tables 7-2 and 7-3. A review of these data shows that the indicator compounds are associated with both carcinogenic and noncarcinogenic health effects in humans and/or experimental animals and toxic effects in aquatic biota and/or terrestrial wildlife. Although it is evident that the contami- nants detected in Union Lake are associated with adverse health and environmental effects, dose-response relationships and the potential for human and environmental exposure must be evaluated before the risks to receptors can be determined.

The most applicable information on dose-response relationships are current standards, criteria, and guidelines that provide a quantitative indication of the potency of a compound. Applicable and relevant standards and criteria include MCLs, MCLGs, EPA Health Advisories, Ambient Water Quality Criteria (AWQC), State of New Jersey guidelines, Carcinogenic Potency Factors (CPFs) and Acceptable Chronic Intakes (AICs).

Table 7-4 lists the standards, criteria, and guidelines for the indicator compounds selected to evaluate potential public health and environmental risks. A discussion of the assumptions and limitations associated with these parameters follows.

- Carcinogenic Potency Factor - Carcinogenic risks are estimates of the probability, or range of probabilities, that a specific adverse carcinogenic effect will occur. The Carcinogenic Potency Factor (CPF) is an estimated 95% upper-bound confidence limit of the carcinogenic potency of the chemical, i.e., there is a 95% chance the risk is at or below this calculated value. CPFs are expressed as the lifetime cancer risk per mg of body weight per day. CPFs are used to convert the estimated dose of a compound to incremental lifetime cancer risks by multiplying the chronic daily intake (over 70 years) by the CPF.

  The CPF used for arsenic via the oral route of ingestion is 1.8 mg/kg/day. This value is based on a reinterpretation of an earlier Taiwanese study of arsenic exposure via arsenic drinking water using a "multi-stage" cancer model (USEPA, October 1986). The CPF used for 4,4'DDE was that given for DDT because there is no value given for 4,4'DDE and because of the chemical similarities between DDE and DDT.

- Acceptable Chronic Intakes - Acceptable intakes for chronic exposure (AIC) are based on the amount of a compound (in mg/kg/day for a 70 kg adult) that is not expected to result in adverse non-carcinogenic health effects after chronic exposure to the general population (including sensitive subgroups). AICs are determined from the highest quantitative indication of toxicity (i.e., No-Observed Adverse Effect Level) derived from human or animal

TABLE 7-2

CARCINOGENIC POTENCY FACTORS FOR CONTAMINANTS FOUND IN UNION LAKE[1]

Chemical	Oral Route (mg/kg/day)$^{-1}$		Inhalation Route (mg/kg/day)$^{-1}$	
Arsenic, As	1.8[2]	CAG, A2[4]	15	CAG, A
Chromium, Cr	NA		41	HEA, A
Nickel, Ni	NA	A	1.7 (NiS)	HEA, A
			0.84 (dust)	HEA, A
PCBs	7.00	CAG, B2	------	
Chlordane	1.3	ODW, B2	------	
4,4' DDE[3]	0.34	HEA, B2	------	

1 USEPA, OSWER Dir 9285.4-1, update Nov 16, 1987.

2 CPF for arsenic is based on applying a multistage model to data from human epidemiologic studies rather than using the more conservative absolute risk linear model (Reference 1).

3 No CPF is given for 4,4'DDE; therefore the value for DDT was used.

4 B2 = Suspected human carcinogen (based primarily on animal studies). A = Known human carcinogen.

TABLE 7-3

TOXICITY DATA FOR NONCARCINOGENS[1]

Chemical	Oral Route (mg/kg/day) Subchron (AIS)	Chronic (AIC)	Source	Inhalation Route (mg/kg/day) Subchron (AIS)	Chronic (AIC)	Source
Antimony, Sb	--	4.00E-04	RfD	---	---	---
Barium, Ba	--	5.70E-02	IRIS	1.4E-3 (T)	1.4E-04	HEA
Chromium III	14.0	1.00	RfD	---	---	---
Chromium VI	2.5E-02	5.00E-03	HEA	---	---	---
Copper, Cu	3.7E-02	3.7E-02	HEA	---	1.00E-02	HEA
Lead, Pb	--	1.4E-03[3] (0.57E-03)	HEA	---	---	---
Mercury, Hg (org)	2.80E-04	3.00E-04	RfD	---	---	---
Mercury, Hg (inorg)	1.40E-03	1.40E-03	RfD	---	---	---
Nickel, Ni	1.4E-02	1.00E-02	HEA	---	---	---

1 USEPA, OSWER Dir 9285.4-1, update Nov. 16, 1987.

2 Based upon 50 ug/l MCL of lead in water; value in parenthesis based upon 20 ug/l of lead in water, the MCGL.

TABLE 7-4

WATER QUALITY REGULATORY CRITERIA

Chemical Samples	Safe Drinking Water Act MCLs (ug/l)	Clean Water Act Quality Criteria for Human Health Health Fish of and Drinking Water (ug/l)	Criteria for Human Health for Drinking Water Only (ug/l)	Safe Water Drinking Act Health Advisories (ug/l) 1-day	10-day	Longer Term[e]	New Jersey Water Standard Ground Water Quality Criteria (ug/l)	New Jersey Water Standards Surface Water Quality for FW2 Waters (ug/l)	NJPDES Max Conc. of Constituents for Groundwater Protection (ug/l)	Sediment Range[c] mg/kg	Water Range	Frequency of Occurrence in Water (Mean)[b] (ug/l)
Arsenic	50	0 (2.2 ng/l)	(25 ng/l)	-	-	-	50	50	50	u-1273[a]	48-75(60.6)	16/16
Barium	1000			-	-	-	1000	1000	1000	21-166	49-92(56)	28/28
Beryllium		0 (6.8 ng/l)	0(3.9 ng/l)	-	-	-				u-2.9	u	0
Cadmium	10	10	10	43	8	5, 18	10	10	10	u	u-2	1/28
Chromium[d]	50	50	50	1400	1400	240, 840	50	50	50	u	2-21(6.2)	17/28
Copper		1000	1000							16-45	u	0
Lead	50 (20)	50	50	-	-	20, 20	50	50	50	u-50	12-24(17)	3/28
Mercury	2	144 ng/l	10	-	-		2	2	2	u	u-12(4.2)	4/28
Nickel		13.4	15.4	-	1000	-				13-26	6-18(11)	20/28
Zinc		5000	5000	-	-	-	50			u-90	u	0

u=Undetected
a=Includes samples by NJDEP
b=Mean based on Ebasco phase I water samples, Table 4-4
c=Based on two samples, except for arsenic
d=Criteria are given for Cr (VI)
e=First value for 10 kg child, second value for 70 kg adult. Values for lead are 20 mg/day.

toxicity studies. AICs are used to evaluate the potential for noncarcinogenic effects associated with exposure to site-related hazardous constituents.

- Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs) - National Primary Drinking Water Standard Maximum Contaminant Levels (MCLs), promulgated under the Safe Drinking Water Act, are enforceable standards for contaminants in public drinking water supply systems. MCLs are based on a lifetime exposure to a contaminant for a 70 kg adult consuming 2 liters of water per day. MCLs are calculated to reflect exposure to a contaminant from all sources (air, food, water, etc.). They consider not only health factors, but also the economic and technical feasibility of removing a contaminant from a water supply system. Secondary Drinking Water Standard MCLs are nonenforceable standards that consider the aesthetic quality of drinking water. The EPA has also proposed MCLGs for several organic and inorganic compounds in drinking water. MCLGs are guidelines and are based on health considerations only. It is important to note for reference that the MCL for arsenic, which is not health based, is 50 ug/l and results in a cancer risk for adults (drinking 2 liters per day for 70 years) of 2×10^{-3} (based on a CPF for arsenic of 1.8 $(mg/kg/day)^{-1}$).

- Health Advisories - Health Advisories are nonenforceable guidelines, developed by the Office of Drinking Water, for chemicals that may be intermittently encountered in public water supply systems. Short-term Health Advisories are calculated for a 10 kg child (one year old infant) who ingests one liter of water per day for two exposure levels: 1 day, and 10 days. Lifetime Health Advisories are calculated for a 70 kg adult assumed to drink two liters of water per day. Longer Term Health Advisories (1 to 2 years) are calculated for both a 10 kg child and a 70 kg adult. These guidelines do not consider carcinogenic risks or synergistic effects. Health Advisories are used to evaluate the potential for acute and chronic health effects associated with the ingestion of contaminated drinking water.

- Ambient Water Quality Criteria - Ambient Water Quality Criteria (AWQC) are nonenforceable guidelines for the protection of human health from exposure to contaminants in ambient water. These criteria are estimates of the concentrations that will not produce adverse health effects in humans and, for known or suspected carcinogens, the concentrations associated with incremental lifetime cancer risks of 10^{-4} (one additional case of cancer in 10,000 people exposed) through 10^{-7} (one additional case of cancer in 10,000,000 people exposed). AWQC have been used by many states to develop enforceable ambient water quality standards. These criteria are used to evaluate the

potential for non-carcinogenic and carcinogenic health risks associated with exposure to contaminants in drinking water.

- o New Jersey PDES Maximum Concentrations of Constituents for Drinking Water - These are the standards written into NJPDES Permits. Alternates may be established as per NJAC 7:14A-6.15(e)2.

A comparison of the concentrations of lead and mercury in the water samples with the water quality criteria in Table 7-4 enables a better evaluation of these contaminants as indicator chemicals. Lead was detected in the water in three out of 28 samples, and as discussed earlier, those samples were from the bottom water of the lake which may have contained some sediment. The mean lead concentration of those three samples is 17 ug/l, which is below the MCLG for lead in water. For this reason lead was not used as an indicator chemical in water. Mercury was detected in four out of 28 water samples. Three of those concentrations were below 0.4 ug/l, which is well below the MCL for mercury. The fourth value was 12 ug/l. Since only one of the samples was above the MCL, mercury was not considered further as an indicator chemical in water.

7.2 EXPOSURE ASSESSMENT

Based on the environmental features of the Union Lake area, along with the possible activities of receptor populations, the following seven exposure pathways were initially considered to be potentially significant:

- o Ingestion of vegetables and/or forage crops;
- o Ingestion of lake water;
- o Ingestion of soil/lake sediment;
- o Ingestion of fish;
- o Inhalation of soil/former lake sediments;
- o Direct contact with soil/lake sediment; and
- o Direct contact with lake water.

Five of these pathways were, after an initial screening analysis, carried through the exposure assessment. The rationales for selecting these five pathways are presented below.

7.2.1 Ingestion of Vegetables and/or Forage Crops

Ingestion of vegetables and crops which may be irrigated with Union Lake water was considered but rejected as a possible exposure pathway because the lake water is not actually used for irrigation.

Union Lake's large water storage capacity (approximately three billion gallons), in an area of New Jersey that is typically devoid of large surface water impoundments, makes it an ideal potential source of irrigation water. Since arsenic was found in the lake water and is known to accumulate in vegetable and forage crops (USEPA, 1980); and there is a potential for Union Lake water to be used for irrigation purposes, the ingestion of vegetable and/or forage crops was initially considered a potential exposure pathway. However, closer examination of the use of Union Lake showed that, at the present time, the lake water is not utilized for irrigation at large or small growing areas (i.e., adjacent farmland or small residential gardens, respectively). Therefore, evaluation of the ingestion of vegetables irrigated with Union Lake water was not performed in the risk assessment.

7.2.2 Ingestion of Lake Water

The ingestion of lake water was considered as a possible exposure pathway. Union Lake's primary use is as a recreational area for swimming, boating and fishing. A municipal bathing beach is adjacent to the spillway at the southeastern end of the lake. Recreational boating is widespread on the lake. The lake water is not used as a drinking water source. However, the incidental ingestion of lake water during recreational activities is a possible exposure pathway. Arsenic has been found in the lake water, therefore the incidental ingestion of Union Lake water was evaluated in the risk assessment.

7.2.3 Ingestion of Soil/Lake Sediment

There is the potential for Union Lake sediment to be ingested during recreational use of the lake. This exposure route was evaluated in the risk assessment. While intentional ingestion is unlikely, contaminated lake sediment may inadvertently be ingested by persons swimming and/or by children playing in shallow water. In addition, normal fluctuations in the lake's water level may expose varying amounts of contaminated sediments that may accidentally be ingested during playing and other normal outdoor activities. Therefore sediment ingestion was evaluated in the risk assessment as discussed in detail in Subsection 7.3.1.

7.2.4 Ingestion of Fish

Fishing is a common activity in Union Lake. Since arsenic, chlordane, 4,4'DDE and Arochlor 1260 were detected in Union Lake fish and lead and mercury are known to bioaccumulate in fish species (USEPA, 1980), the ingestion of fish was considered an important pathway and was evaluated in the risk assessment.

7.2.5 Inhalation of Soil/Former Lake Sediment

During windy days, surface soil particles can become easily entrained and transported for great distances in the air column.

These suspended soil particles may have contaminants adsorbed to them and may potentially be inhaled by people. During periods when Union Lake is filled to capacity, contaminated lake sediments are not exposed. However, during the repair of the spillway and dam, lake sediments may be exposed as lakeshore soils when the water is lowered. These soils may become entrained in air by lakeshore activities and wind. Since contaminants were found in the Union Lake sediments, the inhalation of soil/former lake sediments was evaluated as a possible exposure pathway for periods of time typical of the dam repair.

7.2.6 Direct Contact with Lake Sediment

During swimming, wading, fishing and boating, the possibility exists for people to contact contaminated lake sediments. In many cases after contact with lake sediments, the exposed body parts are also partly washed off as they are pulled through a column of water. Bottom sediments may be resuspended in lake water during swimming, boating and as a result of weather conditions. This activity also brings sediment into contact with the body surface. Contamination in the sediments can be absorbed through the skin. However, since adequate models are not available to address exposures via this route, it was not quantitatively evaluated.

7.2.7 Direct Contact with Lake Water

As stated previously, Union Lake is utilized as a recreation area. Since the people come in contact with the lake water through recreational activities, the direct contact with Union Lake water was considered a potential exposure pathway. Dissolved contamination in the water can be absorbed through the skin and was evaluated in the risk assessment.

In summary, the following five exposure pathways were considered likely and are addressed further in Subsection 7.3:

- Ingestion of Lake Water;
- Ingestion of Soil/Lake Sediment;
- Ingestion of Fish;
- Inhalation of Soil/Former Lake Sediment; and
- Direct Contact with Lake Water.

7.3 QUANTITATIVE EXPOSURE MODELS

Human exposure or chemical intake at a site must be determined to assess the health effects associated with the site. If an intake criterion were known, e.g., if the USEPA's standard for ingesting indicator chemical A were 0.5 mg/day, then the determination of whether or not the contaminated medium posed a threat to human health would be a comparison of the exposure at a site with the standard. For example, if the soil at a site

contained 500 mg/kg of chemical A, and a particular receptor typically ingested soil at the rate of 0.6 g/day, the receptor would have an intake rate of 0.3 mg/day of chemical A (fraction of soil containing chemical A times the amount of soil ingested). In this example, the hypothetical site would not have an adverse public health effect for the ingestion of chemical A in soil because the calculated intake of chemical A is less than the allowable intake.

Applicable intake criteria do not exist for all the exposure pathways of chemically contaminated media at a given site. In addition, calculating the total exposure via several pathways requires a site specific evaluation of each medium or matrix. A method to evaluate the potential health impacts resulting from each intake route must be developed. The method consists of deriving models which reflect the transport of contaminants from the source to the receptors.

Such models are especially useful to predict long term chronic exposures. The pathways are expressed as a series of algebraic equations describing site specific intakes. Two sets of pathway models were derived; one to estimate the maximum or worst case exposure of receptors to a contaminant, and one to estimate a more realistic or most probable exposure. By comparing the results of the two sets of models, the range of risks that exposed populations may experience can be determined.

For non-carcinogens, exposure pathways were evaluated by comparing site-specific intake rates of indicator contaminants with acceptable intake rates, based on available toxicological, chemical and physical characteristics of the contaminants of concern. Exposure pathway and matrix specific intake rates for these chemicals were calculated utilizing worst case pathway modeling. The acceptable intake rates for each chemical were then compared to the calculated matrix-specific intake rates to initially determine if a potential human health risk existed via the worst-case model. When the ratio of the site-specific intake to the acceptable intake exceeded one, the site possibly presented a hazard and intake rates were re-evaluated using more plausible pathway models. The non-carcinogenic acceptable daily intakes are listed in Table 7-3.

For carcinogens, potential health impacts were evaluated by calculating the cancer risk caused by exposure to various contaminated matrices (e.g., sediment or water). The site-specific intake rate for each carcinogen via the worst case and most probable exposure pathways were calculated and multiplied by the cancer potency factor to calculate the cancer risks. This calculated risk was compared to a target risk range of 10^{-4} to 10^{-7}. The equations used to calculate risks are summarized in Table 7-5.

TABLE 7-5

SUMMARY OF EQUATIONS USED TO
CALCULATE CHRONIC DAILY INTAKES FOR UNION LAKE[a]

Equation	Expression	
7-1	Sediment Ingestion	
	CDI =	$\frac{(SC)(IRS)\ (\%ABS)\ (EVT)\ (EXP)}{(BW)\ (365\ days)(70\ years)\ (1000)}$
7-2	Lake Water Ingestion	
	CDI =	$\frac{(WC)\ (WI)(\%ABS)\ (EVT)\ (EXP)}{(BW)(365\ days)(70\ years)}$
7-3	Fish Ingestion	
	CDI =	$\frac{(FC)(FI)(\%ABS)(EXP)}{(BW)(70\ years)}$
7-4	Sediment Inhalation	
	CDI =	$\frac{(SC)(SAA)(\%ABS)(BR)(EXP)(FC)(10^{-6})}{(BW)(70\ years)}$
7-5	Lake Water Dermal Absorption	
	CDI =	$\frac{(WC)(Flux)(TW)(\%ABS)(EVT)(EXP)(SA)}{(BW)(365\ days)(70\ years)}$

a) To calculate CDIs for carcinogens, CDI is calculated for each age group, and the lifetime weighted-average CDI is used to assess cancer risks. For noncarcinogens, the CDI_t for the most heavily exposed age group is compared to the acceptable daily intake for the pollutant of concern.

Definitions

1. CDI = Chronic Daily Intake (mg/kg/day)
2. SC = Soil Concentration (mg/kg)
3. IRS = Soil Ingestion Rate (g/day for age group)
4. % ABS = Percent Take up by Body (for age group)
5. EVT = # of Events per year (for age group)
6. EXP = Years of Exposure (for age group)

TABLE 7-5 (Cont'd)

SUMMARY OF EQUATIONS USED TO
CALCULATE CHRONIC DAILY INTAKES FOR UNION LAKE(a)

7. BW = Body Weight (kg for age group)
8. WC = Water Concentration (mg/l)
9. WI = Water Ingested (l/day)
10. FC = Fish Concentration (mg/kg)
11. FI = Fish Ingestion Rate (kg/day)
12. BCF = Biocconcentration Factor for Contaminent (l/kg)
13. Flux = Flux Rate of Water Across Skin ($mg/cm^2/hr$)
14. D = Time of Exposure (hours)
15. SA = Body Surface Area (cm^2)
16. SAA = Suspended Sediment Concentration (mg/m^3)
17. BR = Breathing Rate (m^3/day)
18. FC = Fraction of Inhaled Particulate that came from Blackwater Branch
19. TW = Time of Exposure to Water/Hours

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7.3.1 Ingestion of Lake Sediment

As discussed in Subsection 7.2.3, the ingestion of lake sediment can occur when people play or swim in shallow waters. While intentional sediment ingestion is very unlikely, accidental ingestion may occur in shallow water and in areas at the water's edge which are exposed through wave action or through water level fluctuations. Also, sediment may be ingested after a person gets wet and later dries; a certain amount of sediment may be dried on the body and later be ingested when eating or engaging in other hand-to-mouth activities.

It must be emphasized that the pathway considered in this scenario applies only to sediments in the very shallow water, either above or just (a few feet) below the water level of the lake. Contact with deeper sediments may also occur during swimming, but this pathway was not addressed in the analysis.

Two scenarios were developed to describe recreational exposures to Union Lake sediments (and surface water, as discussed below).

The most probable case (residents near the lake) assumes that children will spend the most time at the lake and in the water during the summer swimming season, and that adults and infants (age 0-2) will come into contact with water and sediment less frequently. The total days of exposure for children and teenagers was assumed to be 40 days/year (approximately four days/week during summer vacation) and seven days for adults and infants. The worst case scenario (avid swimmers, lifeguards) assumes 80 days of exposure for children and teenagers and 40 days per year of exposure for adults and infants.

For the most probable case, the average time spent in contact with water was assumed to be 2.6 hours per swimming day. This value is recommended as a representative average by EPA's Superfund Exposure Assessment Manual (USEPA, 1986). For the worst case scenario, four hours per day in water/sediment contact was assumed.

The worst case estimates for sediment exposure (50-200 mg/day, depending upon the age group) are derived from a study by Lagoy (1987) which summarizes observations of soil intakes in residential settings, that assume essentially full-time, year-round exposures through activities such as outdoor play and gardening. For the most probable case, these values were adjusted in an attempt to take into account differences in behavior of the various age groups and the relatively shorter periods of time spent at the lake than at home. The values derived for each age group (10-80 mg/day) by this method are summarized in Table 7-6.

TABLE 7-6

PARAMETERS FOR RECREATIONAL EXPOSURES TO UNION LAKE WATER AND SEDIMENT

Physical Parameters

Population	Age	Body Weight kg	Surface Area cm^2
Infant	0-2	8.95	2.00E+03
Young Child	2-6	17	6.80E+03
Child	6-10	28.4	1.02E+04
Child	11-14	45.3	1.15E+04
Child	15-18	59.7	1.75E+04
Adults	18-70	70	2.0E+04

Site Exposure Parameters

Population	Days at Lake/Yr		Hours/day at Lake		Years Exposure	Soil Ingestion Rate g/day	
	Worst Case	Most Probable Case	Worst Case	Most Probable Case		Worst Cast	Most Probable Case
Infant (0-2)	40	7	4	2.6	2	1.00E-01	5.00E-02
Young Child (2-6)	80	40	4	2.6	5	2.00E-01	8.00E-02
Child (6-10)	80	40	4	2.6	5	1.00E-01	5.00E-02
Child (11-14)	80	40	4	2.6	3	5.00E-02	1.00E-02
Child (15-18)	80	40	4	2.6	3	5.00E-02	1.00E-02
Adults (18-70)	40	7	4	2.6	52	5.00E-02	1.00E-02

Water Ingested = 100 ml (2 mouthfuls/day) Worst case; 50 ml (1 mouthful/day) most probable case

Water flux through skin = 0.5 $mg/cm^2/hr$

%ABS for arsenic (ingestion) = 100%
(inhalation) = 30% (most probable case), 80% (worst case)
(dermal contact from water) = 6.0% adults, 12% child (up to 10 yers)

% ABS for mercury (inorganic) = 15%
(methyl) = 100 %

% ABS for lead = 50% for children
15% for adult

% ABS for DDT = 100%

% ABS for gamma BHT = 35%

% ABS for Endosulfan sulfate = 100%

% ABS for TCE = 100%

BCF for mercury (inorganic) = 5500 l/kg

Average fish ingestion for US = 6.5 g/day above age 6 (most probable case)
= 37 g/day above age 6 and 6.5 g/day below age 6 (worst case).

SAA = 0.17 mg/m^3 (air dust cone)

BR = 37.7 m^3/day (worst case); 12.8 m^3/day (most probable case) (breathing rate)

FC = 10% (fraction of suspended particulate coming from Blackwater Branch)

Note: Inhalation evaluated for a 5 year drought, therefore exp. = 5 years

Studies of arsenic ingestion have shown that 100% of the arsenic ingested was found in the blood stream (Section 3). Most of these studies were of arsenic dust, arsenic oxide (As_2O_3), or arsenic in water. The bioavailability of arsenic in the lake sediment for ingestion is probably less than for the forms studied. However, since the stomach is acidic, much of the arsenic may be freed from the sediment during ingestion. Since more detailed information on arsenic sediment ingestion is not available, 100% absorption of arsenic from sediment ingestion was assumed.

The speciation and form of the arsenic in the sediments was not measured. As discussed in Section 3, the absorption, excretion, and toxicity of arsenic is determined by both its species and form, i.e., As (III), As (V), and organic or inorganic compounds. Winka (1985) and Faust (1983) studied the various forms of arsenic in Union Lake and determined that As (V) and organic forms of arsenic were present in measureable quantities in the sediment. There are significant experimental and analytical uncertainties in determining the speciation. Due to these uncertainties and the uncertainties in the digestion and metabolism of arsenic compounds, complete (100%) absorption of ingested arsenic by the bloodstream was used even though this is probably a conservative number. For lead, gastrointestinal absorption factors of 50% (children) and 15% (adults) were used, as discussed in EPA's Health Effects Assessment of Lead (USEPA, 1984).

In the sediment pathway, it is assumed the receptors have a certain incidental sediment ingestion rate and that some proportion of the sediment ingested for that day is lake sediment adjusted to the person's age and behavior as discussed above. The age groups considered for these models were presented in Table 7-6. The amount of lake sediment ingested is calculated for each year and age group-specific daily intakes (CDIs) are calculated for use in assessing non-carcinogenic risks. For carcinogenic risks, a lifetime daily intake rate is determined taking the weighted average of the intakes for each age group. This staged model attempts to factor in those periods, usually in childhood, in which a chronic daily intake may be different than that for an adult because of behavior, body weight, exposure, etc. Mathematically, the model for the sediment ingestion pathway for each age group is expressed in Equation 7-1 on Table 7-5. The values chosen for each parameter and age group in Equation 7-1 were presented in Table 7-6.

Using the worst case exposure assumptions and the maximum sediment arsenic concentration (1273 mg/kg), the lifetime CDI for arsenic is 4.5×10^{-4} mg/kg/day, which corresponds to a lifetime cancer risk of 7×10^{-4}. The most probable case exposure assumptions, using the windsorized mean value for lake

sediment arsenic concentrations (74.2 mg/kg) result in a lifetime CDI for sediment ingestion of 4.3×10^{-6} mg/kg/day, and a corresponding lifetime cancer risk of 6×10^{-6}.

For lead, the other indicator chemical of concern, the highest CDI for any age group (2-6 years) was 6.4×10^{-5} mg/kg/day. This value is much lower than the chronic acceptable daily intake value of 5.7×10^{-4} mg/kg/day. Therefore, it appears that lead in the sediment is unlikely to pose a health risk through direct ingestion.

An acute or subchronic exposure to arsenic of as little as 0.05 mg/kg/day in soy sauce, arsenic (III) in solution, and arsenic sulfide in medicines has been noted to cause observable toxic effects (USEPA, 1984). For the worst case of subchronic arsenic poisoning, a scenario was considered in which a young child (2-6 years) weighing 17 kg eats a significant amount of sediment containing 1273 mg/kg of arsenic. Using this scenario, the amount of sediment ingested would have to be 0.67 g/day to receive a dose of 0.05 mg/kg/day. This may be possible for a pica child but is well above the estimated average intake values. This also assumes all the ingested arsenic is absorbed by the bloodstream. Assuming a median concentration of 74.2 mg/kg of arsenic, the corresponding amount of sediment to be ingested to cause acute or subacute adverse effects is 11.5 g/day.

7.3.2 Ingestion of Lake Water

As discussed previously, a model was also developed to assess the possible risks associated with incidental ingestion of lake water during recreational activities, primarily swimming. As for sediment ingestion, two scenarios (most probable and worst case) were developed for water ingestion. The exposure assumptions regarding the amounts of time spent at the lake were the same as those described for sediment ingestion. For the worst case assessment it was assumed that 100 ml (about two mouthfuls) of water would be ingested per swimming day. For the most probable case, a value of 50 ml/day water ingestion was assumed. Mathematically, the model for this incidental lake water ingestion is described by Equation 7-2 in Table 7-5.

The maximum concentration of total arsenic (dissolved and particulate) measured in Union Lake was 81 ug/l during Phase I sampling in June and July of 1986 (Table 4-1). The arsenic concentration was lower in winter as described in Section 3, However, the winter arsenic values were not used in the risk assessment because they are not representative of the season during which recreational water use occurs. The mean value of the total arsenic in the summer was 67.4 ug/l (Table 4-4).

Using the worst case exposure assumptions and the maximum total arsenic concentrations in Union Lake water results in a lifetime CDI of 2.7×10^{-5} mg/kg/day, corresponding to a lifetime cancer risk of 4×10^{-5}. The most probable case assumptions and the average arsenic concentrations give a lifetime CDI of 3.7×10^{-6} mg/kg/day and a lifetime cancer risk of 6×10^{-6}. Inorganic lead, and the other organic pollutants are not of concern in this pathway, but are of concern in the fish ingestion pathway as will now be discussed.

7.3.3 Ingestion of Fish

Sports fishing is a common recreational activity on Union Lake. Arsenic and other contaminants are known to accumulate in animal tissues. The bioconcentration of contaminants in the fish and their subsequent ingestion was modeled for specific age groups as in Equation 7-3 in Table 7-5. The parameters are noted in Table 7-6.

Samples of fish caught in Union Lake were analyzed for arsenic, pesticides, and PCBs. Six to seven fish of each of five species (two catfish, one sucker, one sunfish, and one pickerel) were caught and sent for analysis. The fish samples were fillets containing muscle tissue and skin prepared as described in Subsection 5.1.2. Table 7-7 lists the amounts of contaminants detected in the fish.

The amount of fish caught in Union Lake and eaten by the local or recreational population has not been studied. However, the average fish ingestion rate for the U.S. has been estimated to be 6.5 g/day (USEPA, 1980). This rate is not broken down by age group. In observations of eating habits of children under six, young children eat very little fish in general and even less sport fish. Therefore, for the most probable case, a fish consumption value of 6.5 g/day will be used, except for children under six (see Table 7-6). Populations that depend more heavily on sports fishing for their food (based upon studies of sports fishing in contaminated lakes in the Western U.S.), may average 37 g/day of fish consumed. This latter value is probably high for most of the population around Union Lake but will be used as the worst case estimate for fish ingestion.

In the absence of pollutant-specific data for fish ingestion, it will be assumed that all (100%) of the ingested arsenic and organic pollutants (Chlordane, DDE, and PCBs) are absorbed into the body after ingestion of contaminated fish. It will again be assumed that the arsenic in the fish tissue has the same carcinogenic potency factor as the inorganic arsenic [a mixture of primarily As(+5) with some As(+3)] mixture for which the CPF was developed. As will be discussed below, this result is probably an overestimate of the actual arsenic-associated risk. For all the organic pollutants, CPFs derived by EPAs Carcinogen

TABLE 7-7

CHEMICAL CONTAMINATION IN FISH
FROM UNION LAKE (mg/kg)

Chemical	Concentration Range	Mean of Detected Values	Frequency of Occurrence
Arsenic	0.020-0.240	0.133	6/6
Chlordane	0.005-0.072*	0.030	6/6
4,4'DDE	u-0.160	0.104	3/6
Arochlor 1260	u-0.400	0.240	3/6

*Four values were detected below the contract-required detection limit.

u = undetected

Assessment Group were used to assess carcinogenic risk. The exception is DDE, for which the CPF for DDT (the most closely-related compound for which data were available) was used to assess cancer risks.

The results of the risk assessment for the fish ingestion pathway are given in Table 7-8. The total lifetime cancer risks (summed across all pollutants) are 2×10^{-4} for the most probable case scenario and pollutant concentrations, and a 2×10^{-3} for the worst-case scenario and the highest measured contaminant levels. In both scenarios, the bulk of the risk (over 75%) is due to PCBs, a family of pollutants not known to be site-related. DDE accounts for less than 1.5% of the risk under both scenarios, and arsenic (using the CPF for inorganic species) accounts for about 10% of the risk in both scenarios.

The maximum concentration of arsenic detected was 0.24 mg/kg and the mean was 0.133 mg/kg (Table 7-7). The worst-case cancer risk from arsenic for eating fish is 2×10^{-4}. A more realistic arsenic cancer risk from the mean arsenic concentration and average U.S. fish ingestion rate is 3×10^{-5}. This is a high value also because it assumes children under six have the same fish ingestion rate as older children and adults. If exposure of a child under six is subtracted, the cancer risk is 2×10^{-5}.

While pesticides/PCBs were detected in the fish in Union Lake, the lake water and sediments were not analyzed for these compounds. Pesticides/PCBs were found only sporadically in the sediments and water upstream from the lake during other portions of the site investigation. The PCB Arochlor 1260, which yields the highest risk estimate from fish ingestion, was not found in any of the sediment or water samples taken upstream from the lake. Since PCBs are not known to be associated with the ViChem plant site, the source of the Arochlor 1260 in the lake fish is not known. PCBs are known to have a high bioconcentration factor (USEPA, January 1986); therefore a relatively low concentration in the lake sediments or water may produce a detectable concentration in the fish. While outside the scope of this investigation, the nature and extent of the PCB contamination in the lake water and sediments may be determined by the USEPA in a future study.

7.3.4 Inhalation of Soil/Former Lake Sediment

During the dam reconstruction project, the lake's water level will be lowered by approximately eight to nine feet, depending on the flow. This period is expected to last for three years (June, 1987 to June, 1990). During this period, institutional controls are expected to restrict access to the lake for recreational purposes so that the exposure pathways described in Subsections 7.3.1 through 7.3.3 are no longer a concern. However, during a drought period where no institutional controls

TABLE 7-8

CONTAMINANT INTAKE AND CANCER RISK ESTIMATES FOR UNION LAKE FISH INGESTION PATHWAY

CONTAMINANT	MOST PROBABLE CASE		WORST-CASE	
	CDI[a]	CANCER RISK	CDI[a]	CANCER RISK
ARSENIC	1.3×10^{-5}	2×10^{-5}[b]	1.4×10^{-4}	2×10^{-4}
CHLORDANE	2.9×10^{-6}	4×10^{-6}	4.3×10^{-5}	6×10^{-5}
DDE	1.0×10^{-5}	3×10^{-6}	9.5×10^{-5}	3×10^{-5}
PCBs	2.3×10^{-5}	2×10^{-4}	2.4×10^{-4}	2×10^{-3}
TOTAL	-	2×10^{-4}	-	2×10^{-3}

[a] mg/kg/day

[b] excludes exposure of children under six years old.

controls prevent lake access, those pathways will still be a concern. As discussed in Section 2, it is unlikely that the lake's water level will naturally go below the dam spillway. However if this were to occur, lake sediments would be exposed.

During periods when sediments are exposed, resuspension of the former lake sediments as dust in the air may occur. The inhalation of these contaminated dusts could cause exposure to arsenic.

The inhalation of dust can be expressed mathematically for each age group by Equation 7-4 in Table 7-5.

Most probable and worst case exposure estimates were developed to assess potential exposure to individuals living near the exposed sediment. Since exposure would occur in a residential setting, it was assumed that, in both scenarios, exposures would occur 365 days per year. Because exposures were being estimated only for the three-to-five year drawdown period, exposures were assessed only for the groups that would receive highest exposures during this period. Because of their higher respiratory volume, adults were the most exposed group. Children, who have a larger respiratory volume per body weight, would receive a higher dose during the period of exposure than adults, but the higher absolute respiratory rate for adults results in higher overall doses, when averaged over a lifetime. For the most probable case, a respiratory volume of 12.8 m^3/day was used. This corresponds to 16 hours/day exposure (assuming eight hours per day in "clean" indoor environments or commuting to unpolluted areas), 90% at rest and 10% at moderate activity as defined by EPA's Exposure Assessment Manual (USEPA, January 1986). The worst-case scenario assumes 24 hours per day exposure, 60% at rest, 35% moderate activity, 5% heavy activity, for a total daily respiratory volume of 37.7 m^3/day, corresponding to a heavily exposed individual who lives and works near the exposed sediment and has an outdoor job requiring moderate activity.

In the absence of direct measurements of airborne particulate levels, two assumptions were made about the levels and compositions of sediment to which residents would be exposed. The first assumption is that the average total airborne particulate level near the lake would be 0.017 mg/m^3, corresponding to a representative rural particulate level (USEPA, 1986). The second assumption is that, on average, the sediment from Union Lake would make up 10% of the total airborne particulate. As was the case with the sediment ingestion pathway, the worst case scenario assumed a sediment arsenic level of 1273 mg/kg, corresponding to the highest measured value found in the bottom sediment, and the most probable case estimate made use of mean sediment level of 74.2 mg/kg. Neither of these values may be representative of the arsenic levels actually present in exposed sediment.

The most probable exposure estimate for this pathway results in a lifetime average CDI of 3.0×10^{-10} mg/kg/day for a three-year exposure period and 5.0×10^{-10} mg/kg/day for a five-year exposure period. These intake values correspond to lifetime cancer risk estimates of 2×10^{-8} and 3×10^{-8}, respectively, for the three- and five-year exposure periods. The CDIs calculated using the worst case scenario were 6.7×10^{-7} and $1.1. \times 10^{-6}$ mg/kg-day, respectively, for the three- and five-year exposure periods, corresponding to lifetime cancer risks of 2×10^{-6} and 3×10^{-6}.

7.3.5 Direct Contact with Lake Water

Swimming and other water recreation in Union Lake leads to direct skin contact with the lake water. The contaminants in the lake water can be absorbed by the skin and pass into the bloodstream. A model was developed for lake water exposure. The USEPA Superfund Assessment Manual (USEPA, January 1986), uses the dermal flux, the amount of water passing through the skin, to evaluate the amount to solute passing from the water to the bloodstream. This is expressed mathematically, for each exposure age group, in Equation 7-5 in Table 7-5.

The value of (%ABS) is the amount of solute which can pass through the skin along with the water and then go in the bloodstream. Skin is not equally permeable to all solutes in water. Studies on arsenic have shown that the arsenic uptake from water is not 100%, but is closer to 1.8% (Dutkiewicz, 1977). For conservatism, the value of the fraction of arsenic absorbed by the skin is taken to be somewhat higher, 6% for adults and 12% for children under 12 years. This is multiplied in Equation 7-5 by the flux to account for a smaller fraction of arsenic passing from the water through the skin and into the bloodstream.

To assess risks for the most probable case, the mean total arsenic concentration in Union Lake water was used (67 ug/l). For the worst case assessment, the maximum value (87 ug/l) was used.

The worst case scenario yielded a lifetime CDI for arsenic of 4.9×10^{-7} mg/kg/day, corresponding to a lifetime risk of 7×10^{-7}. The lifetime CDI and cancer risks for the most probable case were 9.0×10^{-8} mg/kg-day and 1×10^{-7}, respectively.

7.4 PUBLIC HEALTH IMPACTS FOR UNION LAKE

In order to provide a better description of the risks associated with different assumptions concerning lake usage and water level conditions, the exposures via the various routes were combined into four lake usage scenarios, and total population cancer risks were calculated for each usage scenario.

The scenarios which were evaluated were:

1) A "normal lake" scenario, in which the lake is assumed to be at its normal level for the entire 70-year exposure period. Under this scenario, total risks are calculated by summarizing the risks associated with all of the water and sediment-related pathways, as shown in Table 7-9.

2) Three years of dam repair. In this scenario, it is assumed that the lake will be in its drawn down condition for three years, during which time institutional controls would prevent all water and sediment contact exposures. Risks for this scenario thus assume 67 years of "normal" exposure conditions and three years during which the inhalation pathway (sediment is exposed during drawdown) would be the only pathway contributing to risk.

3) Five years of dam repair. This scenario is the same as Scenario 2, except that the repair period (and the period of inhalation exposure) is assumed to be five years.

4) Repair and drought. This scenario assumes a three-year repair period, followed by an additional three-year drought period during which water levels remain low and sediment remains exposed. It is also assumed that there will be no institutional controls which would prevent sediment or lake water contact during the drought period. Thus, both the sediment/water and inhalation pathways will contribute to risks during the drought period.

The risk for Scenario 1, the "normal" lake usage scenario, are summarized for each exposure pathway in Table 7-9.

The risks calculated for Scenarios 2 through 4 did not differ significantly from the risk for the normal case, as summarized in Table 7-10. Because the sediment ingestion and the water ingestion and direct contact pathways were associated with much higher risks than the inhalation pathway for exposed sediments, risks associated with the former exposure routes dominated the risks for all the scenarios, when the full 70-year exposure period is considered.

Since the major determinant of total 70-year risks is the number of years that the sediment ingestion and water exposure pathways are operative, the risks for Scenarios 2 through 4 all vary by less than 10% from "normal" risks. This difference is not significant given the level of uncertainty surrounding the risk assessment. Even if sediment inhalation risks were ten-fold higher, the risks calculated for Scenarios 2 through 4 would still not vary from the "normal" risks by more than 10%.

TABLE 7-9

SUMMARY OF CANCER RISKS FOR EXPOSURE PATHWAYS AT UNION LAKE

Pathway	Estimated Lifetime Cancer Risks	
	Most Probable	Worst Case
Exposed Sediment Ingestion	6×10^{-6}	7×10^{-4}
Lake Water Ingestion	6×10^{-6}	4×10^{-5}
Lake Water Dermal Contact	1×10^{-7}	7×10^{-7}
Total for Recreational (non-fishing) Exposure	1×10^{-5}	7×10^{-4}
Exposed Sediment		
Inhalation (drawdown or drought)	1×10^{-8} [a] 2×10^{-8} [b]	2×10^{-6} [a] 3×10^{-6} [b]
Fish Ingestion	2×10^{-4}	2×10^{-3}

[a] Risks for three-year drawdown.

[b] Risks for five-year drawdown.

TABLE 7-10

ARSENIC CANCER RISKS FROM UNION LAKE
FOUR SCENARIOS OF LAKE CONDITIONS

WORST CASE	SEDIMENT	WATER	INHALATION	TOTAL
Scenario 1				
Normal Lake 70 Years	7×10^{-4}	4×10^{-5}	0	7×10^{-4}
Scenario 2				
Normal Lake 67 Years	7×10^{-4}	4×10^{-5}	0	7×10^{-4}
Construction 3 Years	0	0	2×10^{-6}	
Scenario 3				
Normal Lake 65 Years	7×10^{-4}	4×10^{-5}	0	
Construction 5 Years	0	0	3×10^{-6}	7×10^{-4}
Scenario 4				
Normal Lake 64 Years	6×10^{-4}	4×10^{-5}	0	
Construction 3 Years	0	0	2×10^{-6}	
Drought Condition 3 Years	3×10^{-5}	2×10^{-6}	2×10^{-6}	7×10^{-4}
MOST PROBABLE CASE:				
Scenario 1				
Normal Lake 70 Years	6×10^{-6}	6×10^{-6}	0	1×10^{-5}
Scenario 2				
Normal Lake 67 Years	6×10^{-6}	6×10^{-6}	0	
Construction 3 Years	0	0	2×10^{-8}	1×10^{-5}
Scenario 3				
Normal Lake 65 Years	6×10^{-6}	6×10^{-6}	0	
Construction 5 Years	0	0	3×10^{-8}	1×10^{-5}
Scenario 4				
Normal Lake 64 Years	5×10^{-6}	5×10^{-6}	0	
Construction 3 Years	0	0	2×10^{-8}	
Drought Condition 3 Years	3×10^{-7}	3×10^{-7}	2×10^{-8}	1×10^{-5}

7.5 CONSIDERATIONS FOR REMEDIAL ALTERNATIVES

Union Lake is an impoundment of the Maurice River approximately eight miles downstream from the ViChem plant site. Previous investigations have shown that discharges from this plant have resulted in elevated arsenic concentrations in the Blackwater Branch, the Maurice River downstream from the Blackwater Branch to Union Lake, Union Lake, and the Maurice River below Union Lake. Other investigations are being conducted as part of this work assignment to quantify the arsenic contamination at the ViChem plant site, the Maurice River and Blackwater Branch upstream of Union Lake, and the Maurice River below Union Lake.

Remedial alternatives for Union Lake must consider that this lake is a part of a dynamic river system and will constantly receive surface water inflow. The concentration of arsenic in the incoming surface water will influence the concentration of arsenic in the lake's water, as will the amount of arsenic desorbing from the lake's sediments. Therefore remedial alternatives for the lake's water cannot be established until the upstream sources of arsenic are fully understood.

Arsenic levels in bottom sediments are also likely to be affected by the transport of arsenic contaminated water or sediment from the Maurice River. Therefore, any remedy for arsenic contamination in submerged sediment also needs to take these factors into account. Defining remedies for submerged sediment is also complicated by the fact that no precise method exists for assessing the human health risk associated with exposures. Human populations are not likely to come in contact with sediments outside of designated swimming areas, or in areas where depths are greater than several feet. It must also be noted that sediments may be redistributed on the lake bottom through time, so that "clean" areas may become contaminated and vice versa through natural sediment redistribution processes.

Remedial alternatives for the exposed or very shallow sediments, should EPA determine that the calculated risks are unacceptable, are never the less feasible. The alternatives may include removing, treating, or capping sediments so that public access to sediments with unacceptably high arsenic concentrations is minimized or eliminated.

The pathway models used to calculate the risks from human exposure to arsenic in the sediment can be used to back calculate sediment arsenic concentrations that would produce target risk levels. This can be used as a planning tool by EPA to evaluate cleanup alternatives. It must be noted that the sediment arsenic cleanup levels apply only to sediments in exposed or very shallow areas, because the pathway models calculate risks from human exposure to sediments in shallow water and sediments exposed at the water's edge.

Table 7-11 presents the risks calculated for sediments at various arsenic concentrations. The data show that a target risk level of 1×10^{-5} from all of the sediment pathways discussed would be achieved with a sediment arsenic concentration of approximately 120 mg/kg, if most probable case exposure assumptions are used, and 20 mg/kg if the worst case exposure assumptions are used. A target risk level of 1×10^{-6} could be achieved for all of the sediment pathways at arsenic concentrations of approximately 12 mg/kg or 2 mg/kg, respectively, using most probable or worst case assumptions. The latter value is very close to the normal detection limit of arsenic in sediment/soil. The data in Table 7-11 are based on sediment exposure only, not the surface water or fish ingestion exposure pathways.

The presence of pesticides/PCBs in the lake water and sediments was not determined in this investigation. Because the PCB Arochlor 1260 was found in fish tissue, it is possible that PCBs are associated with the lake water or sediments. PCBs were not found in the river upstream of the lake, and are not thought to be associated with the ViChem plant. While outside the scope of this investigation, the presence of PCBs in the lake water and sediments may be determined by the EPA in a future investigation.

Should EPA determine that the calculated fish ingestion risks are unacceptable, remedial alternatives could consist of institutional controls to ban fishing from the lake along with periodic monitoring.

TABLE 7-11

CALCULATED RISKS FROM SEDIMENTS
AT VARIOUS ARSENIC CONCENTRATIONS

Calculated Risk[1]	Sediment Arsenic Concentration (mg/kg)[2]	
	Most Probable Exposure Assumptions	Worst Case Exposure Assumptions
1×10^{-4}	1120	200
1×10^{-5}	120	20
1×10^{-6}	12	2
1×10^{-7}	1.2	0.2

1 Calculated risks assume sediment exposure pathways only.

2 Contract Laboratory Program contract required detection limit for arsenic in soil/sediment is approximately 2 mg/kg.

8.0 SUMMARY OF THE REMEDIAL INVESTIGATION

This section summarizes the RI conducted for the Union Lake portion of the ViChem work assignment.

8.1 BACKGROUND

The Union Lake RI is one of three RIs being prepared for the ViChem site. The site is ranked as one of the top ten hazardous waste sites in New Jersey and is number 42 on the National Priorities List.

Previous investigations have shown elevated arsenic concentrations in the lake's surface water and sediment. This RI was undertaken to perform a risk assessment on the lake and to perform a feasibility study on any media found to pose increased health risks to exposed populations.

The NJDEP has restricted access to the lake while the lake is drawn down for construction of the new spillway. This is due to the arsenic contamination in the lake sediments.

8.2 SITE FEATURES

Union Lake is located in the city of Millville, New Jersey. An impoundment of the Maurice River, the lake has been used extensively by the local population for recreational activities, including swimming, boating, and fishing. The lake is not used as a source of potable or irrigation water.

The dam at the southern end of the lake was constructed in 1868 and is the oldest in the state. The dam spillway is currently being rebuilt. During this construction, the water level of the lake has been lowered approximately eight to nine feet.

Much of the area surrounding the lake is undeveloped woodland, although there are approximately 25 homes fronting the lake and an additional 110 homes within one-half mile of the lake. The area around the lake is seen as having minimal potential for future development.

8.3 HAZARDOUS SUBSTANCES INVESTIGATION

Based on the results of the risk assessment, it was determined that the only hazardous substance of concern in the lake sediments and water is arsenic. Arsenic concentrations above 50 ug/l, the Federal Primary Drinking Water standard (MCL) for arsenic, were found in many water samples. Arsenic concentrations above 20 mg/l, the background arsenic concentration for soil in New Jersey, were found in many sediment samples.

Arsenic exists in the environment in four oxidation states: the (-3) state, the metallic (0) state, and the (+3) and (+5) states. Arsenic occurs most frequently in nature in the pentavalent state as arsenate.

Previous investigations have found that arsenic occurs primarily in four forms in Union Lake: As(III), As(V), monomethylarsenic acid (MMAA), and dimethylarsenic acid (DMAA). These arsenic species can be present in different proportions in sediments and water.

The arsenic in the sediment has been previously shown to be associated with increased organic content and/or increased percent silt and clay content in the sediment. The calculated partition coefficient (Kd) for arsenic in sediment ranges between 179 and 7642.

Chronic arsenic poisoning in humans produces a range of symptoms including hyperpigmentation in several body areas, hyperkeratosis (precancerous skin lesions), and chromosome aberrations. Chronic oral arsenic exposure increases the risk of skin cancer.

Studies have shown that arsenic is not bioconcentrated to a high degree and that lower forms of aquatic life may accumulate more arsenic residues than fish. Bioaccumulation factors (BCF) in fish vary widely. Most workers agree that the BCF for arsenic is somewhere between 1 and 100.

8.4 SURFACE WATER AND SEDIMENT INVESTIGATION

Ebasco conducted its Union Lake investigations in two phases. Phase I took place in June and July of 1986. Surface water and sediment were sampled, and a bathymetric map of Union Lake was prepared. Phase II took place in January of 1987. Surface water and fish were sampled.

The NJDEP and others have also performed various studies of the surface waters and sediments in the lake. Extensive use of the previous data was made in this RI report.

The arsenic concentrations in the surface water were higher in the summer and early fall than in winter in many of the studies, including Ebasco's Phases I and II. In general the dissolved arsenic concentrations, determined from samples filtered in the field, were uniform throughout the water column. Particulate and/or total aqueous arsenic concentrations tended to be higher in water samples taken at the sediment/water interface.

Several trace metals were found in Ebasco's unfiltered water samples. Their presence was attributed to particulates within the samples, since the same trace metals were seen in the sediments, and the trace metals concentrations were highest, in general, in the bottom unfiltered water samples.

The maximum arsenic concentration in sediments from Ebasco's Phase I sampling was 107 mg/kg. Previous NJDEP investigations found sediment arsenic concentrations as high as 1273 mg/kg. The arsenic contamination was generally restricted to the top one foot of sediment in the NJDEP studies. The highest concentrations were generally found near the submerged dam in the northern portion of the lake and adjacent to the main dam in the southern portion of the lake.

8.5 BIOTA INVESTIGATION

Fish samples were obtained from three different locations in the lake. Five separate species were caught and analyzed. The analytical results showed that the fish contained arsenic as well as chlordane, DDE, and PCB 1260. These results were used in the risk assessment.

8.6 TREATABILITY STUDIES

Treatability studies were performed on the sediment after determining that exposure to the sediment posed an increased health risk. Chemical fixation and extraction tests were performed. The results showed that both were feasible methods to treat arsenic-contaminated sediment, reducing the toxicity such that the sediment could be disposed of as non-hazardous material. Both treatment technologies will be evaluated in he FS (Ebasco, 1989f).

8.7 RISK ASSESSMENT

The risk assessment considered a number of different exposure pathways to the arsenic found in the various environmental media. Risks were calculated for the lake under four different lake full/lake drawdown scenarios. Risks were calculated on a worst-case basis and on a most probable case basis. The worst-case risk from sediments and water was estimated to be 7×10^{-4} under all four lake full/lake drawdown scenarios. The most probable case risk from sediments and water was estimated to be 1×10^{-5} under all four lake full/lake drawdown studies. These calculations assume that all of the arsenic is in the form of As (III) and As(V) in the same ratio as was found in the original study used as the basis for calculating arsenic's CPF.

The fish ingestion pathway was evaluated for arsenic as well as for other organics found in the fish. Of the total fish ingestion risk, approximately 86% resulted from the presence of PCBs thought unrelated to the ViChem site.

Sediment arsenic concentrations which would produce various levels of risk from the sediment exposure pathways were calculated to aid in identifying remedial alternatives. A sediment arsenic concentration of 120 mg/kg results in a risk of 1×10^{-5}, while a concentration of 12 mg/kg calculates to a risk of 1×10^{-6}. These calculations refer to the sediment pathways only, not the water or fish pathways. The calculations are based on the most probable exposure assumptions.

8.8 RECOMMENDATIONS FOR FUTURE WORK

The River Areas RI Report (Ebasco, 1989c) presents a detailed discussion of what is known about the mass balance of arsenic in the watershed. In terms of the lake, it is not known weather the incoming lake water or desorption of arsenic off of the sediments controls the water arsenic concentration. It is important to know this in order to determine what effect remediating the lake sediments would have on the lake water, and to determine the necessity for lake remediation.

The sediments in the lake are part of a dynamic system. These sediments may be redistributed over time through natural processes. Also, since the sampling done in 1986, the lake's water level has been lowered and the upper submerged dam spillway was breached. Prior to remediation, sediment modeling studies should be performed to determine the natural redistribution patterns of sediments in the lake, and confirmational sampling should be performed to determine what effect the lake drawdown and the submerged dam breaching had on the contaminated sediment locations.

The risk assessment calculates increased health risks from ingesting fish from the lake, both from arsenic and PCBs in the fish. However, it was noted that there may be inherent overestimates of risk in the calculations. For arsenic, the calculation may be too conservative since the form of arsenic in the fish is probably a relatively non-toxic organic form. For PCBs, the levels detected in fish are well within acceptable USDA dietary standards. Because of these uncertainties, further consideration and/or study should be given to the significance of the fish ingestion pathway.

The recommendations for future work in Union Lake are as follows:

- Perform sediment desorption studies to determine the leaching rate of arsenic from the sediments.
- Determine the mass balance of arsenic in the watershed. This can be done by measuring the streamflow and arsenic concentration at the USGS gaging station in Norma (upstream from the lake), and currently measuring the flow and arsenic concentration coming out of the lake at the dam

spillway. An additional station could be established on the Blackwater Branch downstream from the ViChem site. This information will determine the load of arsenic both upstream and downstream of the lake, which should help determine if arsenic desorption from the sediments adds arsenic to the lake water column. This answer will aid in determining the overall effectiveness of sediment remedial alternatives.

- Perform sediment modeling studies to determine the natural redistribution patterns of sediments in the lake. This will determine the long term effectiveness of removal of sediments from a portion of the lake.

- Perform further investigations into the fish ingestion pathway, including determining the form of arsenic in the fish and the toxicity of that form. In addition, determine the actual risks posed by the low concentrations of PCBs in the fish, which are presently within recommended USDA dietary standards.

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APPENDIX A

FLORA AND FAUNA OBSERVED IN THE UNION LAKE AREA

APPENDIX A

FLORA AND FAUNA IN THE UNION LAKE AREA

FLORA

Common Name	Scientific Name
Indian Pipe	Monotropa uniflora
British Soldier	Cladonia cristatella
Pyxie Cup	Cladonia phxidata
Round-leaved Sundew	Drosera rotundifolia
Thread-leaved Sundew	Drosera fliformis
Pitcher Plant	Sarracenia purpurea
Pine Barren Heather	Hudsonia ericoides
Broomsedge	Andropogon virginicus
Swamp Pink	Helonias bullata
Goat's rue	Tephrosia virginiana var. glabra
Bush Clover	Lespedeza hirta var. longifolia
Lance-leaved Violet	Viola lanceolata var. vittata
Evening Primrose	Oenothera laciniata
Camphorweed	Heterotheca subaxillaris
Mountain Laurel	Kalmia latifolia
Sheep Laurel	Kalmia augustifolia
Huckleberry	Gaylussacia sp.
Blueberry	Vaccinium sp.
Clammy Azalea	Rhododendron viscosum
Leatherleaf	Chamaedaphne calyculata
Fetter-bush	Leucothoe racemosa
Sweet Pepperbush	Clethra alnifolia
Partridgeberry	Mitchella repens
Cardinal Flower	Lobelia cardinalis
Crimson-eyed Mallow	Hibiscus moscheutos
Pitch Pine	Pinus rigida
Shortleaf Pine	Pinus echinata
White Pine	Pinus strobus
Larch	Larix laricina
Southern White Cedar	Chamaecyparis thyoides
White Oak	Quercus alba
Post Oak	Quercus stellata
Black Oak	Quercus veluntina
Southern Red Oak	Quercus falcata
Scarlet Oak	Quercus caccinea
Chestnut Oak	Quercus primus
Water Oak	Quercus nigra
Willow Oak	Quercus phellos
Blackjack Oak	Quercus marilandica
Red Maple	Acer rubrun
Black Gum	Nyssa sylvatica
Sweet Gum	Liquidambar styraciflua
Sweetbay Magnolia	Magnolia virginiana
Sassafras	Sassofras albidum
Holly	Ilex opaca

FAUNA

Common Name	Scientific Name
Largemouth Bass	Micropterus salmoides
Smallmouth Bass	Micropterus dolomieui
Chain Pickerel	Esox niger
Calico Bass	Promixis nigro-malculatus
White Perch	Morone americana
Yellow Perch	Perca flavescens
Bullgill Sunfish	Lepomis macrochirus
Pumpkinseed	Lepomis gibbosus
Mud Sunfish	Acantharchus pomotis
Blue-spotted Sunfish	Enneacanthus obesus
Yellow Bullhead	Ameiurus natalis prothistius
Northern Brown Bullhead	Ameiurus n. nebulosus
White Catfish	Ictalurus catus
Tadpole Madtom	Schelbeodes mollis
Fusiform Darter	Hololepis fusiformis
Roach	Notemigonus C. crysoleucus
Eastern Creek Chubsucker	Erimyzon o. oblongus
Dwarf White Chubsucker	Castostomus commersonic utawana
Salt-water Killifish	Fundulus heteroclitus
Barred Killifish	Fundulus d. diaphanus
Mud Minnow	Umbra pygmaea
Pirate Perch	Aphredoderus sayanus
Striped Bass	Roccus saxatilus
Northern Two-lined Salamander	Eurycea b. bislineata
Northern Red Salamander	Pseudotriton m. ruber
North Cricket Frog	Acris c. crepitans
Folwer's Toad	Bufo woodhousei fowleri
Northern Spring Peeper	Hyla c. crucifer
Bullfrog	Rana catesbeiana
Green Frog	Rana clamitans
Pickerel Frog	Rana Palustris
Southern Leopard Frog	Rana pipiens sphenocephala
Wood Frog	Rana sylvatica
Common Snapping Turtle	Chrysemys p. picta
Spotted Turtle	Clemmys guttata
Red-bellied Turtle	Pseudemys rubriventris
Stinkpot	Sternothaerus odoratus
Eastern Box Turtle	Terrapane c. carolina
Northern Black Racer	Coluber c. constrictor
Timber Rattlesnake	Crotalus h. horridus
Black Rat Snake	Elaphe o. obsoleta
Eastern Hognose Snake	Helerodon platyrhinos
Eastern Kingsnake	Lampropeltis g. getulus
Northern Water Snake	Pituophis m. melanoleucus
Northern Pine Snake	Pituophis m. melanoleucus
Northern Brown Snake	Storeria d. dekayi
Eastern Garter Snake	Thamnophis p. pouritus
Timber Rattlesnake	Crotalus horridus horridus
Five-lined Skink	Eumeces fasciatus

Pied-billed Grebe	Podilymbus podiceps
Bald Eagle	Haliaeetus leucocephalus
Great Blue Heron	Ardea herodias
Green Heron	Butorides virescens
Mallard	Anas platyrhynchos
Black Duck	Anas rubripes
Wood Duck	Aix sponsa
Turkey Vulture	Cathartes aura
Red-tailed Hawk	Buteo jamaicensis
Red-shouldered Hawk	Buteo lineatus
Broad-winged Hawk	Buteo platypterus
Osprey	Pandion haliaetus
Shart-skinned Hawk	Accipter velox
Sparrow Hawk	Falco sparverius
Ruffed Grouse	Bonasa umbellus
Bobwhite	Colinus virginianus
American Woodcock	Philohela minor
Spotted Sandpiper	Actitis macularia
Mourning Dove	Zenaidura macroura
Yellow-billed Cuckoo	Coccyzus americanus
Screech Owl	Otus asio
Great Horned Owl	Bubo virginianus
Whip-poor-will	Caprimulgus vociferus
Common Nighthawk	Chordeiles minor
Chimney Swift	Chaetura pelagica
Ruby-throated Hummingbird	Archilochus colubris
Belted Kingfisher	Megaceryle alcyon
Yellow-shafted Flicker	Colaptes auratus
Red-bellied Woodpecker	Centurus carolinus
Yellow-bellied Sapsucker	Sphyapicus varius
Hairy Woodpecker	Dendrocopos villosus
Downy Woodpecker	Dendrocopos pubescens
Eastern Kingbird	Tyrannus tyrannus
Great Crested Flycatcher	Myiarchus crinitus
Eastern Phoebe	Sayornis pheobe
Acadian Flycatcher	Empidonax minimus
Eastern Wood Pewee	Contopus virens
Tree Swallow	Iridoprocne bicolor
Rough-winged Swallow	Stelgidopteryx ruficollis
Barn Swallow	Hirundo rustica
Purple Martin	Progne subis
Blue Jay	Cyanocitta cristata
Common Crow	Corvus brachyrhynchos
Fish Crow	Corvus ossifragus
Carolina Chickadee	Parus carolinensis
Tufted Titmouse	Parus bicolor
White-breasted Nuthatch	Sitta carolinensis
Red-breasted Nuthatch	Sitta canadensis
Brown Creeper	Certhia familiais
House Wren	Thryothorus aedon
Carolina Wren	Troglodytes ludovicianus
Mockingbird	Mimus polyglottos
Catbird	Dumetella carolinensis
Brown Thrasher	Toxostoma rufum

Robin	Turdus migratorius
Wood Thrush	Hylocichla mustelina
Hermit Thrush	Hylocichla guttala
Blue-gray Gnatcatcher	Polioptila caerulea
Golden-crowned Kinglet	Regulus satrapa
Ruby-crowned Kinglet	Regulus calendula
Cedar Waxwing	Bombycilla cedrorus
Starling	Sturnus vulgaris
White-eyed Vireo	Vireo griseus
Yellow-throated Vireo	Vireo olivaceus
Red-eyed Vireo	Vireo olivaceus
Black-and-white Warbler	Mniotilta varia
Prothonotary Warbler	Protonotaria citrea
Blue-winged Warbler	Vermivora pinus
Parula Warbler	Parula americana
Yellow Warbler	Dendroica aestiva
Magnolia Warbler	Dendroica magnolia
Black-throated Blue Warbler	Dendroica caerulescens
Myrtle Warbler	Dendroca caronata
Blackpoll Warbler	Dendroica striata
Pine Warbler	Dendroica pinus
Prairie Warbler	Dendroica discolor
Palm Warbler	Dendroica pelmarum
Ovenbird	Seiurus aurocapillus
Louisiana Water Thrush	Seirus motacilla
Yellowthroat	Geothlypis trichas
Hooded Warbler	Wilsonia citrina
Wilson's Warbler	Wilsonia pusilla
American Redstart	Steophaga ruticilla
House Sparrow	Passer domesticus
Red-winged Blackbird	Agelaius phoeniceus
Orchard Oriole	Icterus spurius
Baltimore Oriole	Icterus galbula
Common Grackle	Quiscalus quisicula
Brown-headed Cowbird	Molothrus ater
Scarlet Tanager	Piranga olivacea
Cardinal	Richmondena cardinalis
Rose-breasted Grosbeak	Pheucticus ludovicianus
Indigo Bunting	Passerina cyanea
Evening Grosbeak	Hesperiphona verpertina
Pine Siskin	Spinus pinus
American Goldfinch	Spinus tristis
White-winged Crossbill	Loxia leucoptera
Rufous-sided Towhee	Pipilo erythrophthalmus
Slate-colored Junco	Junco hyemalis
Chipping Sparrow	Spizella passerina
Field Sparrow	Spizella pusilla
White-throated Sparrow	Zonotrichia albicolis
Fox Sparrow	Passerella iliaca
Song Sparrow	Melospiza melodia
Opossum	Didelphis marsupialis
Short-tailed Shrew	Blarina brevicausa
Eastern Mole	Scalopus aquaticus
Little Brown Bat	Myotis ludifugus

Red Bat	Lasiurus borealis
Eastern Cottontail	Sylvilagus floridamus
Eastern Chipmunk	Tamias striatus
Gray Squirrel	Sciurus carolinensis
Red Squirrel	Tamiasciurus hudsonicus
Southern Flying Squirrel	Glaucomys volans
Beaver	Castor co canadensis
White-footed Mouse	Peromyscus leucopus
Meadow Vole	Microtus pennsylvanicus
Pink Vole	Pitymys pinetorum
Muskrat	Ondatra zibethicus
Norway Rat	Rattus norvegicus
House Mouse	Mus musculus
Red Fox	Vulpes fulva
Raccoon	Procyon lotor
Mink	Mustela vison
Striped Skunk	Mephitis mephitis
River Otter	Lutra canadensis
White-tailed Deer	Odocoileus virginianus

APPENDIX B

LABORATORY REPORT FOR THE CHEMICAL FIXATION OF ARSENIC AND SOLIDIFICATION OF SEDIMENT TREATABILITY STUDY

TREATABILITY STUDIES FOR CHEMICAL FIXATION OF ARSENIC AND SOLIDIFICATION OF SEDIMENT

VINELAND CHEMICAL COMPANY SITE PROJECT
VINELAND, NEW JERSEY

TASK II
FINAL REPORT
December 11,1987

Report Prepared For: EBASCO SERVICES INCOPORATED
REM III PROGRAM
U.S. ENVIRONMENTAL PROTECTION AGENCY
Task Leader: M. Kuo
Site Manager: W. Colvin
Project Identification No. WA-37.2LB8

Report Prepared By: LOPAT ENTERPRISES INCORPORATED
Wanamassa, New Jersey 07712
Project Supervisor: C. Falk
Project Manager: G. Gironda

Proj. I.D. No. WA-37.2LB8
Ebasco: M. Kuo, W. Colvin
Lopat Ent. Inc. Task II Report
December 11, 1987

SEDIMENT SAMPLES

	Untreated Log 87-64	Treatment 1106-84-2	Treatment 1106-85-1	Treatment 1106-85-2
Color	Black	Soil Brown	Soil Brown	Brown to Dark Grey
Physical Characteristics	Sandy, Silty	Cement -like friable solid	Hard clay	Dried mud consistency
Density, g/cc	1.0	2.11	1.83	1.37
Unconfined @8h:	0	0	0	0
Compressive @24h:	0	8460	6000	0
Strength[a] @32h:	0	>9000	8000	0
lbs/ft² @48h:	0	>9000	9000	590

The U.C.S. of 1106-85-2 was 2800 lb/ft² @54 hours and 6400 lb/ft² @ 72 hours

% Increase in Volume due to Treatment	-33[b]	-2[b]	70
% Increase in Weight Due to Treatment	40	79	133

a) U.C.S. was done with a Soiltest Pocket Penetrometer Model CL-700 having a range between 0-9000 lb/ft² in 500 lb. increments. Each reported number is the average of 10 determinations.

b) A negative value represents a volume decrease.

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Lopat Ent. Inc. Task II Report
December 11, 1987

TREATED SEDIMENT SAMPLES

EP TOXICITY TEST RESULTS (in mg/l)

	1106-84-2	1106-85-1	1106-85-2	1106-91-2 (repeat of 1106-84-2)
As	1.5	1.2	1.0	0.80
Ba	0.6	0.5	0.6	0.8
Cd	<0.005	<0.005	<0.005	<0.005
Cr	0.05	0.04	0.01	0.03
Pb	<0.005	<0.005	<0.005	<0.005
Hg	<0.0002	<0.0002	<0.0003	<0.0002
Se	<0.005	<0.005	<0.005	0.009
Ag	<0.01	<0.01	<0.01	<0.01

Proj. I.D. No. WA-37.2LB8
Ebasco: M. Kuo, W. Colvin
Lopat Ent. Inc. Task II Report
December 11, 1987

TREATED SEDIMENT SAMPLES

MEP Test Results of 1106-84-2

	EP Tox	1	2	3	4	5	6	7	8	9	10
As	1.5	0.02	0.14	0.12	0.07	0.07	0.08	0.05	0.07	0.09	0.12
Ba	0.6	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cd	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cr	0.05	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Pb	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Hg	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Se	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Ag	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

MEP Test Results for 1106-91-2
(Treatment the same as 1106-84-2)

	EP Tox	1	2	3	4	5	6	7	8	9
As	0.80	0.32	0.20	0.08	0.05	0.05	0.06	0.05	0.05	0.06
Ba	0.8	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cd	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cr	0.03	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01
Pb	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Hg	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Se	0.009	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Ag	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

ALL RESULTS REPORTED IN MILLIGRAMS PER LITER.

Proj. I.D. No. WA-37.2LB8
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Lopat Ent. Inc. Task II Report
December 11, 1987

LABORATORY TREATMENT OF SEDIMENT

ID#	1106-84-2 (and 1106-91-2)	1106-85-1	1106-85-2
Treatment	#4	#5	#6
Wt.of Sediment	400g	400g	400g
K-20 LS Part A	1.16g	1.16g	1.16g
K-20 LS Part B	.84g	.84g	.84g
Tap Water	20g	55g	119g
Fixative	8g Darco Gro-safe + 48g Class F Fly Ash + 144g Portland Cement Type I	8g Darco Gro-safe + 80g Class F Fly Ash + 160g Lime, Type SA + 80g Portland Cement Type I	8g Darco Gro-safe + 240g Class F Fly Ash + 240g Lime, Type SA

Proj. I.D. No. WA-37.2LB8
Ebasco: M. Kuo, W. Colvin
Lopat Ent. Inc. Task II Report
December 11, 1987

LABORATORY AND SCALE-UP PROCEDURES AND RAW MATERIALS

COSTS FOR TREATED SEDIMENT SAMPLE 1106-84-2 or 1106-91-2

Laboratory Scale	Scale-up (per ton of sediment) Quantity	(cost)	Scale-up (per yd^3 of sediment) (1 yd^3 of sediment=1686 lb) Quantity	(cost)
400g Sediment	2000 lb		1 yd^3 sediment	
20g Tap Water	100 lb		84.31b	
2g K-20 LSC[a]	1 gal	($40.00)	0.843 gal	($33.72)
8g Darco Gro-safe[b]	40 lb	($15.60)	33.7 lb	($13.15)
48g Class F Fly Ash[c]	240 lb	($ 1.26)	202 lb	($ 1.06)
144g Portland Cement Type I[d]	720 lb	($24.12)	607 lb	($20.33)
	TOTAL	$80.98	TOTAL	$68.26

Ingredients were added and mixed in the same order as listed.

---

a) Lopat Enterprises K-20 LSC, $40.00 per gal. FOB Wanamassa, NJ.
b) Darco Gro-safe activated carbon, American Norit Co., $0.39 per lb, FOB Marshall, TX.
c) Class F Fly Ash, Ash Management Corp., $10.50 per ton,(bulk) FOB Trenton,NJ
d) Portland Cement, Saylor's Type I, Coplay Cement Co., $67.00 per ton,(bulk) FOB Nazareth, PA.

NOTE: The above raw materials costs are approximate, as they are determined by a laboratory screening treatment process. In most cases, pilot studies show that site treatment costs will be lower.

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Lopat Ent. Inc. Task II Report
December 11, 1987

SAMPLE PREPARATION

Log 87-64: The sediment sample was in 3 phases. Approximately 30% of the sample was sand, 30% was organic silt and the remainder was liquid. The bucket was stirred as well as possible but there was obvious stratification. To take 400g samples, a 3/4 inch I.D. pipe was plunged into the bottom of the bucket to get a sand sample of approximately 200g. A plastic scoop was used to remove approximately 200g of sediment. The only liquid transferred was that which was reasonably unavoidable.

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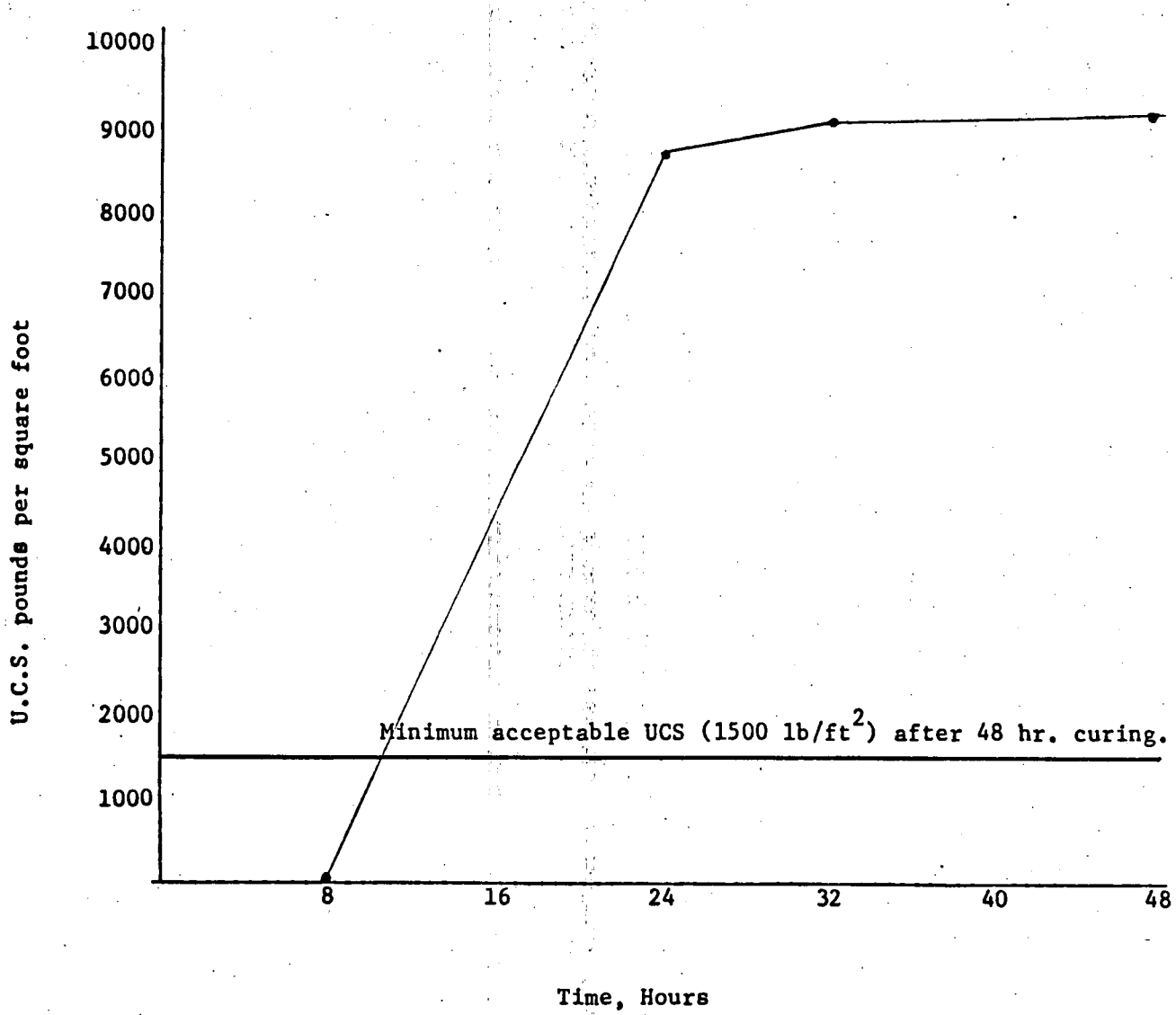
Lopat Ent. Inc. Task II Report
December 11, 1987

Unconfined compressive strength vs. time

Treated Sample: 1106-84-2 Sediment



NOTE: Each plotted point is the average of 10 U.C.S. determinations

Proj. I.D. No. WA-37.2LB8
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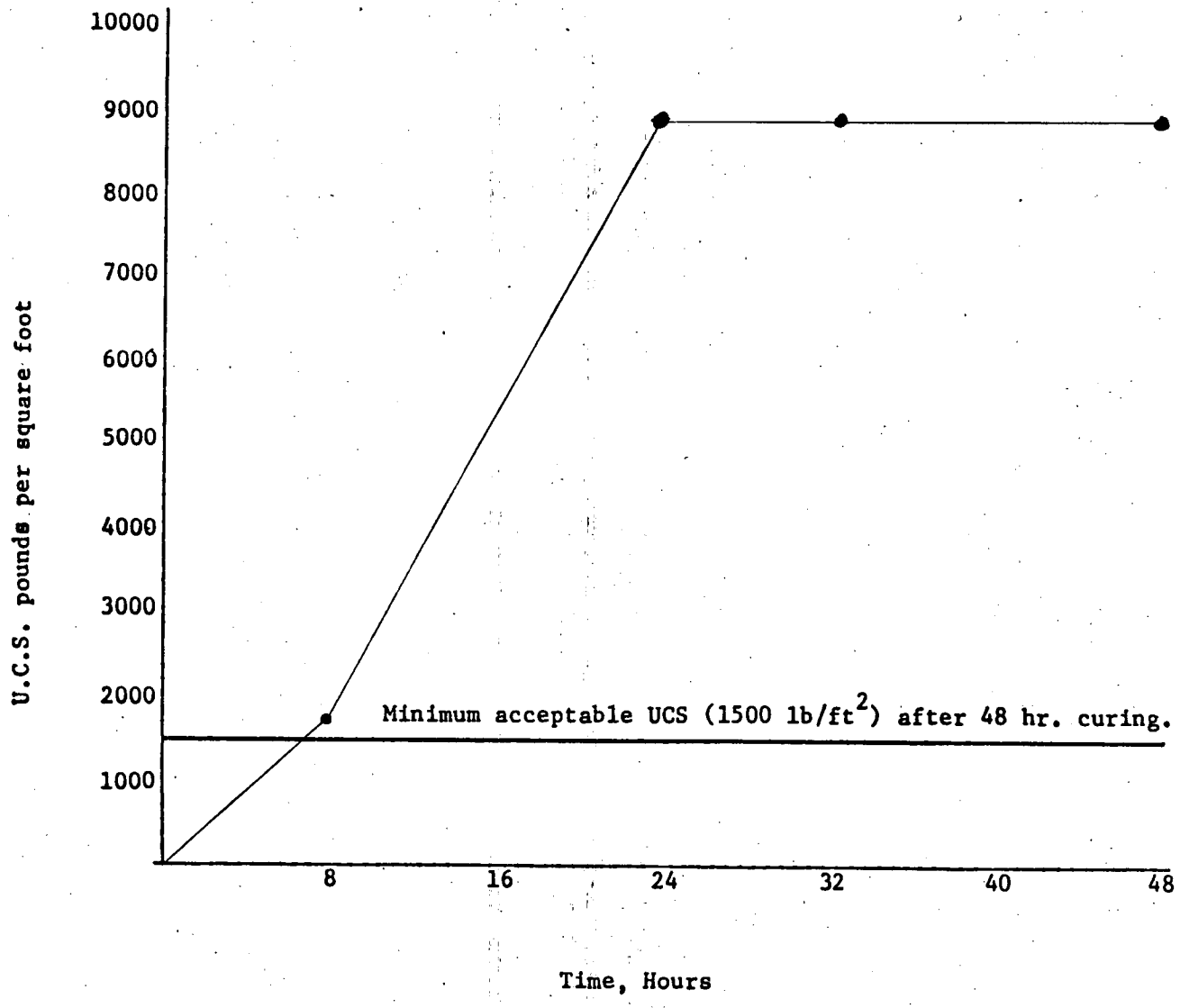
Lopat Ent. Inc. Task II Report
December 11, 1987

Unconfined compressive strength vs. time

Treated Sample: 1106-91-2 Sediment (same treatment as 1106-84-2)



NOTE: Each plotted point is the average of 10 U.C.S. determinations

APPENDIX C

LABORATORY REPORT OF THE EXTRACTION OF ARSENIC FROM SEDIMENT TREATABILITY STUDY

REM III PROGRAM

EPA CONTRACT NO. 68-01-7250

TREATABILITY STUDIES FOR EXTRACTION OF ARSENIC FROM SEDIMENT COLLECTED FROM THE VINELAND CHEMICAL SITE

FINAL REPORT

DECEMBER 9, 1987

HITTMAN EBASCO ASSOCIATES INC.

ESI-1002-601

TABLE OF CONTENTS

		PAGE
I.	INTRODUCTION	1
II.	SUMMARY OF ANALYTICAL METHODS	2
III.	SUMMARY OF RESULTS: SEDIMENT TESTS	3
IV.	DESCRIPTION OF EXPERIMENTS PERFORMED	5
V.	DISCUSSION OF RESULTS	7
VI.	APPENDIX OF LABORATORY DATA	9

I. INTRODUCTION

Sediment samples were collected from the Blackwater Branch and the unlined lagoon located at the Vineland Chemical Company (ViChem) Site in Cumberland County, New Jersey. The sediment samples were combined in a 5 gallon plastic bucket and delivered to the Hittman Ebasco Laboratory in Columbia, Maryland on July 20, 1987. The composite sample was stored in a walk-in cold room at approximately 4°C.

After an initial chemical and physical characterization of the composite sample, bench-scale treatability tests were performed to determine the feasibility of removing arsenic from the solid phase. A number of batch extraction experiments were conducted using tap water, with and without chelating compounds added, at acid, alkali and neutral pH, and at temperatures between 20 and 50°C.

During the treatability work, the scope of the original project was changed. The inability of the batch treatments to consistently produce solids containing less than 20 mg/Kg total arsenic, and the production of relatively large volumes of non-filterable aqueous waste with high suspended solids and arsenic content, made further investigations unwarranted. Therefore, many of the experiments described in the Base-Bid Technical Specifications were eliminated.

This report summarizes the experimental methods, analytical protocols and results of the treatability study performed by personnel from Hittman Ebasco Associates Inc. under the direction of Ebasco Services Incorporated. The results of the sample characterization analyses, a comparison of the efficacy of the extraction agents and an evaluation of the effects of pH and temperature on arsenic removal from the ViChem sediment are presented.

II. SUMMARY OF ANALYTICAL METHODS

Analyte	Method
Aluminum	200.7 (Ref. 2)
Arsenic	7060 (Ref. 1)
Calcium	215.1 (Ref. 2)
Iron	236.1 (Ref. 2)
Total Organic Carbon	9060 (Ref. 1)
% Solids	160.1 (Ref. 2)
Particle Size	ASTM D422

REFERENCES

1. "Test Methods for Evaluating Solid Wastes", EPA SW-846, 3rd Edition, 1986.

2. "Methods for Chemical Analysis of Water and Wastes", EPA-600/4-79-020, 1979.

III. SUMMARY OF RESULTS: SEDIMENT TESTS

A. INITIAL CHARACTERIZATION

	(Total mg/Kg)
Aluminum	13,600
Arsenic	2,870
Calcium	Not detected
Iron	8,890
TOC	70,000
% Solids	11 %

B. ROOM TEMPERATURE EXTRACTIONS WITHOUT CHELATORS

sediment at pH = 3	36 total arsenic (mg/Kg)
sediment at pH = 7*	36
sediment at pH = 12*	14

C. ROOM TEMPERATURE EXTRACTIONS AT pH = 7 WITH CHELATORS

sediment with citrate	21 total arsenic (mg/Kg)
sediment with oxalate	45
sediment with EDTA	37

D. FURTHER EXTRACTIONS WITH CITRATE AT VARIOUS pH AND TEMPERATURE

sediment at pH = 5, T = 24^{o}	21 total arsenic (mg/Kg)
sediment at pH = 7, T = 50^{o}	44
sediment at pH = 5, T = 50^{o}	32

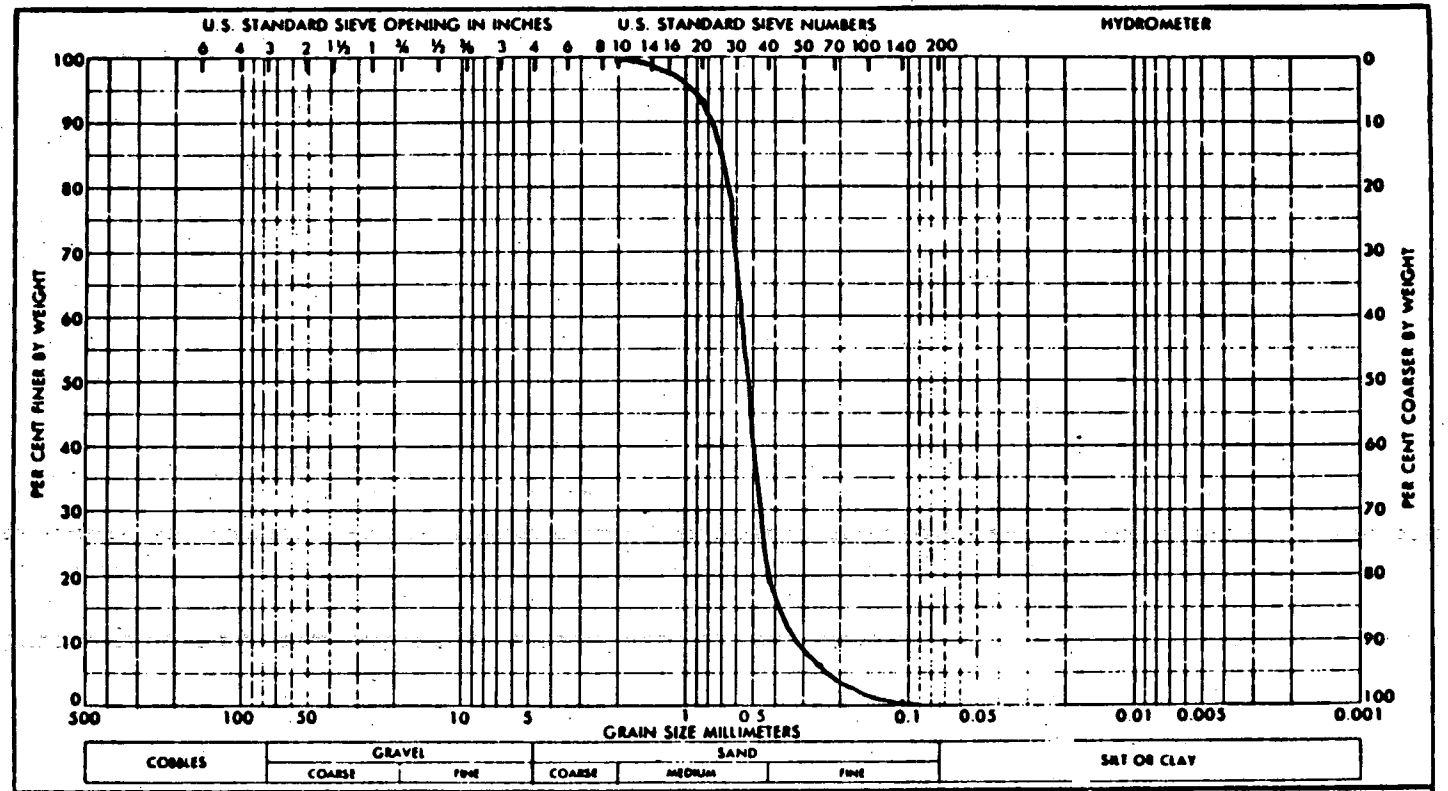
E. PHASE SEPARATION BY SETTLING AND ARSENIC CONTENT

Total volume of suspension: 700 ml

Settling Time	Liquid Volume	Solid Volume
1 minute	570 ml	130 ml
10 minutes	550	150
1 hour	530	170
24 hours	520	180
	unfiltered	washed
Total Arsenic (wet)	82 mg/Kg	2.0 mg/Kg
% solids	4%	80%

* pH values > 5 required large amounts of NaOH and were difficult to maintain.

PARTICLE SIZE - VICHEM SEDIMENT



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI

GRADATION CURVES

PROJECT Vichem Soil

AREA

BORING NO

DATE 7-23-87

IV. DESCRIPTION OF EXPERIMENTS PERFORMED

Simple batch extraction experiments performed on the ViChem sediment sample at room temperature (Section III. A-C) were carried out by combining 200 grams of undried sample with 200 ml of tap water in a 1L pyrex griffin beaker. When chelating agents were added, the following compounds were used in the amounts given below:

Chelator	Grams Added per Beaker
sodium citrate	1.03
sodium oxalate	1.13
tetrasodium EDTA	0.46

These additions resulted in a final concentration of the chelating agent of approximately 0.01 molar. Next, the pH of the solution was adjusted as necessary with 1 + 1 hydrochloric acid or 5N sodium hydroxide.

Solutions were stirred on a Phipps and Bird paddle stirrer at 30-40 rpm for two hours with periodic monitoring and adjustment of pH. After two hours of continous stirring, the solids were allowed to settle for 30 minutes and the supernatant decanted. Retained solids were washed three times with tap water to remove any residual reagent and submitted to the lab for analysis.

Further sediment extractions (Section III. D) were performed with the citrate chelator at various pH and temperature regimes. Each experiment was carried out in a 500 ml 3-neck round bottom reaction flask fitted with a heating mantle, a thermometer and a combination pH electrode. Solutions were stirred at 30-40 rpm for two hours after which the separation and washing of the solids were performed as before.

For the phase separation/settling experiment (Section III. E), 400g of sediment, 400 ml of tap water and 2.06 g sodium citrate were combined to make a suspension of 700 ml total volume. This suspension was stirred rapidly (80-100 rpm) on a paddle stirrer for two hours. Although approximately 20 ml of 5N sodium hydroxide was added during the extraction procedure, the final pH was only (6.3). Immediately after stirring, the solution was poured into a 1000 ml graduated cylinder so that liquid and solid volumes could be measured over a 24-hour period. After the final volume measurements were taken, a 100 ml portion of the organic-rich supernatant was poured off from the top of the cylinder and analyzed for total arsenic. The heaviest solid fraction was then thoroughly washed with tap water to remove all visible organic material and the resulting sand analyzed for total arsenic.

V. DISCUSSION OF RESULTS

The ViChem sediment sample proved to be a difficult matrix on which to perform treatability experiments. The composite sample is a black, soupy, organic-rich sandy sludge. Its natural pH is between 5.5 and 6.5, and because of the large proportion of humic substances, maintaining an extraction pH in excess of this range proved difficult. Addition of sodium hydroxide is not an effective means of raising the pH due to subsequent release of organic acids. Even 400 ml of 5N NaOH was insufficient to keep the pH of the system above 7 toward the end of the two-hour batch extraction experiments. Follow-on field extractions to remove arsenic from the ViChem sediments will require large amounts of reagents and continuous monitoring if these extractions are to be conducted at other than acidic pH values.

As can best be shown by the arsenic content of the liquid and solid phases of the sediment following treatment, the arsenic contained in the ViChem sediment is associated with the organic material and not tightly bound to the sand fraction. Throughout the various extraction experiments, treatments that removed organic material such as solubilization by addition of NaOH followed by decantation and thorough washing, removed the most arsenic from the solid fraction. Chelators, elevated temperatures and pH adjustments between 5 and 7 had little effect in producing solids that met the target criterion of less than 20 mg total arsenic per Kg of dry solids (all arsenic values are expressed on a dry weight basis unless otherwise noted).

In addition to the inability of batch extraction techniques studied herein to meet the 20 mg/kg target, large amounts of aqueous, black, organic-rich, arsenic wastes were produced from decantation of the

extract supernatant solutions and multiple washings of the retained solids. This aqueous waste would have to be treated and treatment for ultimate disposal was not investigated in this study. Reduction of volume by dewatering may prove to be the most difficult step. The very fine contaminated organic suspensions do not settle out. Even after the 24-hour settling experiment, the liquid fraction remained opaque and immediately clogged the large (15 cm diameter) Watman GF/F glass fiber filters used in unsuccessful attempts at filtering through Buchner funnels under vaccuum.

In summary, the batch extraction experiments conducted on the ViChem sediment supplied by Ebasco were not effective in lowering their arsenic content to a level that would comply with disposal protocols. Another serious drawback was the generation of relatively large volumes of aqueous wastes containing leached arsenic and fine suspended particulates that will be difficult to treat by conventional methods. Thus, simple batch extraction treatments using citrate, oxalate or EDTA chelators in combination with elevated temperatures to 50°C and solution pH adjustments between 5 and 12 did not provide conditions favorable for treatment of these contaminated wastes.

VI. APPENDIX OF LABORATORY DATA

QA/QC DATA SUMMARY
LAB CONTROL RESULTS

CLIENT: VINELAND CHEMICAL/SEDIMENTS

CONTRACT NO: ESI -1002-101

UNITS: ARSENIC, ug/L
TOTAL ORGANIC CARBON, mg/L

PARAMETER	QC RESULT	QC TRUE VALUE	% RECOVERY
TOC	1140	1160	98
ARSENIC	82	80	103
TOC	1020	1160	88
ARSENIC	84	80	105
TOC	1020	1160	88

NOTE: Blanks were digested and analyzed during each sample preparation procedure. All blank values were below instrumental detection limits for Arsenic (5 ug/L).

QA/QC DATA SUMMARY
DUPLICATE RESULTS

CLIENT: VINELAND CHEMICAL/SEDIMENTS

CONTRACT NO: ESI -1002-101

UNITS: ARSENIC, ug/L
TOC mg/kg

PARAMETER	SAMPLE ID	SAMPLE RESULT	DUPLICATE RESULT	% DIFFERENCE
ARSENIC	4990	91	104	13
TOTAL ORGANIC CARBON	4910	<100	<100	NON-CALCULABLE

QA/QC DATA SUMMARY
SPIKE RESULTS

CLIENT: VINELAND CHEMICAL/SEDIMENTS

CONTRACT NO: ESI-1002-101

UNITS: ARSENIC ug/L
TOTAL ORGANIC mg/L

PARAMETER	SAMPLE ID	SAMPLE RESULT	SPIKE RESULT	SPIKE ADDED	% RECOVERY	
ARSENIC	4990	91	296	40	513	N
TOC	4910	<100	755	1000	76	

N = SPIKE RECOVERY OUT OF CONTROL WINDOW OF 75 - 125%. MATRIX INTERFERENCE IS INDICATED.

APPENDIX D

FIELD WATER QUALITY RESULTS

VINELAND CHEMICAL COMPANY SITE
SURFACE WATER QUALITY
FIELD TESTS - UNION LAKE

SAMPLE STATION	DESCRIPTION	IN SITU WATER QUALITY TESTS a TEMP.	b pH	c Eh	d D.O.	e S.P. Cond.	f Salinity
	PHASE I						
EL-1	Surface Water	22	6.9	0.57	9.6	95	0
	Bottom Water	21	6.9	0.75	9.4	100	0
EL-2	Surface Water	21.5	6.4	8.6	9.4	95	0
	Bottom Water	20.5	-	-	9.2	100	0
EL-3	Bottom Water						
EL-4	Surface Water	26	5.1	-	7.3	85	0.25
	Mid-Water	24.5	5.0	-	7.5	85	0.25
	Bottom Water	23	-	-	5.4	105	0.25
EL-5	Surface Water	25	6.6	2.8-4.5	7.5	80	0
	Bottom Water	24	6.5	3.4-4.2	7.0	75	0
EL-6	Surface Water	25	6.4	-	9.0	80	0
EL-7	Surface Water	26	5.1	-	8.0	85	0
EL-8	Surface Water	25	6.8	-	8.2	85	0
	Mid-Water	25	6.8	-	7.6	90	0.5
	Bottom Water	22	6.5	-	5.4	87	0.6
EL-9	Surface Water	25	6.4	-	7.2	77	0
	Bottom Water	23.5	6.5	-	6.2	82	0.2
EL-10	Surface Water	24	6.7	1.45	8.4	82	0
	Bottom Water	22.5	6.9	1.45	6.9	82	0
EL-11	Surface Water	24.5	6.4	2.3	8.0	80	0
	Bottom Water	22.5	5.8	2.4	5.8	82	0
EL-12	Surface Water	24.5	6.8	1.75	8.0	80	0
	Bottom Water	21.5	6.8	1.75	5.3	90	0
EL-13	Surface Water	23.5	6.8	0.75	7.8	80	0
	Bottom Water	2.2	6.6	0.75	7.1	85	0
EL-14	Surface Water	2.3	6.7	0.78	7.8	75	0
	Bottom Water	2.3	6.4	0.64	7.6	79	0
EL-15	Surface Water	2.2	6.4	1.15	7.8	80	0
	Bottom Water	20.5	6.8	0.88	7.7	100	0

VINELAND CHEMICAL COMPANY SITE
SURFACE WATER QUALITY
FIELD TESTS

SAMPLE STATION	DESCRIPTION	IN SITU WATER QUALITY TESTS a TEMP.	b pH	c Eh	d D.O.	e S.P. Cond.	f Salinity
	PHASE II						
EL-1	Mid-Water	4	6.5	-200	9.4	50	-
EL-2	Surface Water	4	6.9	-370	9.2	50	-
	Bottom Water	4	7.2	-350	8.8	35	-
EL-3	Surface Water	3	8.0	-360	9.7	55	-
	Bottom Water	3	8.4	-410	10.5	50	-
EL-5	Surface Water	2.5	7.2	-330	10.6	50	-
	Bottom Water	2	6.4	-360	10.9	50	-
EL-8	Surface Water	2.5	6.6	-260	10	40	-
	Bottom Water	3	6.0	-200	9.6	30	-
EL-25	Surface Water	2.5	7.8	-250	8.3	20	-
	Bottom Water	4.5	5.7	-110	10.2	40	0
EL-26[g]	Surface Water	2,3	7.8,6.7	-125,-25	8.9,8.8	55,60	-
	Bottom Water	2,2.5	8.5,7.8	-150,-75	9.6,9.4	60,60	-
EL-27	Surface Water	2.5	8.9	-270	8.6	55	-
	Bottom Water	3	8.0	-200	8.4	55	-
EL-28	Surface Water	4	8.5	-180	7.7	50	-
	Bottom Water	1	9.3	-220	9.4	45	-
EL-29	Surface Water	3	6.0[h]	-370	8.0	40	-
	Bottom Water	3.5	6.0[h]	-320	8.3	45	-
EL-30	Mid-Water	2	6.7	-200	8.4	70	-

a - Temperature, °C
b - pH, S.U.
c - Eh, millivolts
d - Dissolved Oxygen, mg/l
e - Specififc Conductance, umhos/cm
f - Salinity, %
g - Results of duplicate sample
h - pH taken with wide-range paper